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Aquatic Study of the lower Colorado River

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TABLE OF CONTENTS

Page

List of Tables ii

List of Figures iii

I. Recent History of the Colorado River 1

II. River Habitats - 1976 40

III. Life Histories of Important Native and Sport Fish 56

Threadfin Shad 57
Rainbow Trout. 63
Channel Catfish. 73
Striped Bass 84
Largemouth Bass. 94
Black Crappie. 110
Bluegill 119
Bonytail Chub. 130
Humpback Chub. 133
Razorback Sucker 137

IV. Fish Diseases and Parasites. 143

V. Aquatic Plants 153

VI. Aquatic Invertebrates 156

VII. Appendices 159

1. Timeline of major events in the development of the Colorado River. 160
2. Dredging and channelization in the lower Colorado River 1949-1974 161

Aquatic Plants of the Colorado River

3. Algal groups from the Colorado River 167
4. Aquatic vascular plants of the Colorado River. . . . 171
5. Major emergent and riparian plant species. 179
6. Vascular plants with aquatic affinities reported from the vicinity of the Colorado River. 204

Page

Aquatic Invertebrates of the Colorado River.

7. Distribution of aquatic invertebrates in the Colorado River 214
8. Zooplankton groups reported from the Colorado River 246
9. Common aquatic invertebrates and their importance to the fishery 247
10. Habitat types and representative invertebrate groups from the Colorado River 248

VI. Bibliography. 250

LIST OF TABLES

1. Extreme flows of the Colorado River 6

2. Invertebrate species from the Colorado River in Glen Canyon 13

3. Native fish species of the Colorado River and associated tributaries 16

4. Date of first introduction of major exotic game and forage fish to the Colorado River 29

5. Fish species found in backwaters of the lower Colorado River 47

6. River-mile designations, lengths, and estimated percentages of bank modifications through rip-rap or other armoring techniques, or inundation, for 10 operational divisions of the lower Colorado River, 1973 53

7. Comparison of growth rates of striped bass from Lake Mead and other waters and comparison of growth between Lake Mead and naturall produced striped bass 89

8. Development time of eggs and sac fry of largemouth bass vs. water temperatures. 99

9. List of identified and reported bacterial and viral diseases, parasites and fungal infections found associated with fish in the Colorado River system between Hoover Dam and the International Boundary. 144

10. U.S. Fish and Wildlife certifiable diseases 149

11. List of diseases and pathogens which the Colorado River Wildlife Council indicates fish should be free from before being stocked in the Colorado River drainage (adopted in 1973, amended in 1974, 1976, 1978 and 1980) . . 151

LIST OF FIGURES

		Page
1.	Colorado River and its major tributaries	2
2.	Colorado River in the study area ca. 1900	3
3.	Mean discharge of the Colorado River at two points on the lower river, prior to the construction of Hoover Dam	5
4.	Silt load of the Colorado River prior to and after the construction of Hoover Dam	7
5.	Suspended matter at two points on the lower river prior to the construction of Hoover Dam	8
6.	Mean TDS in the lower Colorado River 1926-1929	10
7.	Mean monthly water temperature at three points on the lower Colorado River	11
8.	Monthly average temperatures of the Colorado River at Willow Beach prior to and after the filling of Lake Mead	22
9.	Monthly mean discharge of the Colorado River at Lee Ferry prior to and after the construction of Glen Canyon Dam	34
10.	Mean TDS at two points on the lower Colorado River	37
11.	Colorado River in the study area, 1976	40
12.	Location map for fish diseases and parasites	146

APPENDIX FIGURES

1.	Overall map of the study area	163
2.	Detail map of Region 1	164
3.	Detail map of Regions 2 and 3	165
4.	Detail map of Regions 4 and 5	166

I. Recent History of the Colorado River.

When the Spanish explorer Hernando de Alarcon first discovered the Colorado River in 1450, it was a far different river than the one we are familiar with today. There were no great dams backing up clear lakes or extensive diversion works and canal systems carrying water to thirsty fields and cities. The river de Alarcon traveled from its mouth to the present day town of Ehrenburg was red with silt and meandered through flat desert valleys. Transitory backwaters and marshes were strung along beside it and great cottonwood galleries lined most of its length. Two years later another Spanish explorer, Lopez de Cardenas, discovered the Grand Canyon, but sheer walls prevented him from reaching the turbulent river below (USDI - Bur. Reclam. 1946).

The Colorado River rose in the Rocky Mountains of Colorado and wound through the plateaus and canyons of Colorado and Utah to Arizona (fig. 1). The river from Lees Ferry, Arizona consisted of two distinct sections (fig. 2). The upper section from Lees Ferry to the Black Canyon had an average gradient of 8 feet/mile (Dill 1944). This was the river of turbulent rapids and steep canyons that came to symbolize the Colorado River. Here the river cut down through the uplifting rock and formed the Grand Canyon. The river in the Canyon area was well supplied with tributary streams draining off the high plateaus and mountains above. The Paria, Virgin, Muddy and Little Colorado Rivers and numerous smaller tributaries fed into the river along its course through the canyons.

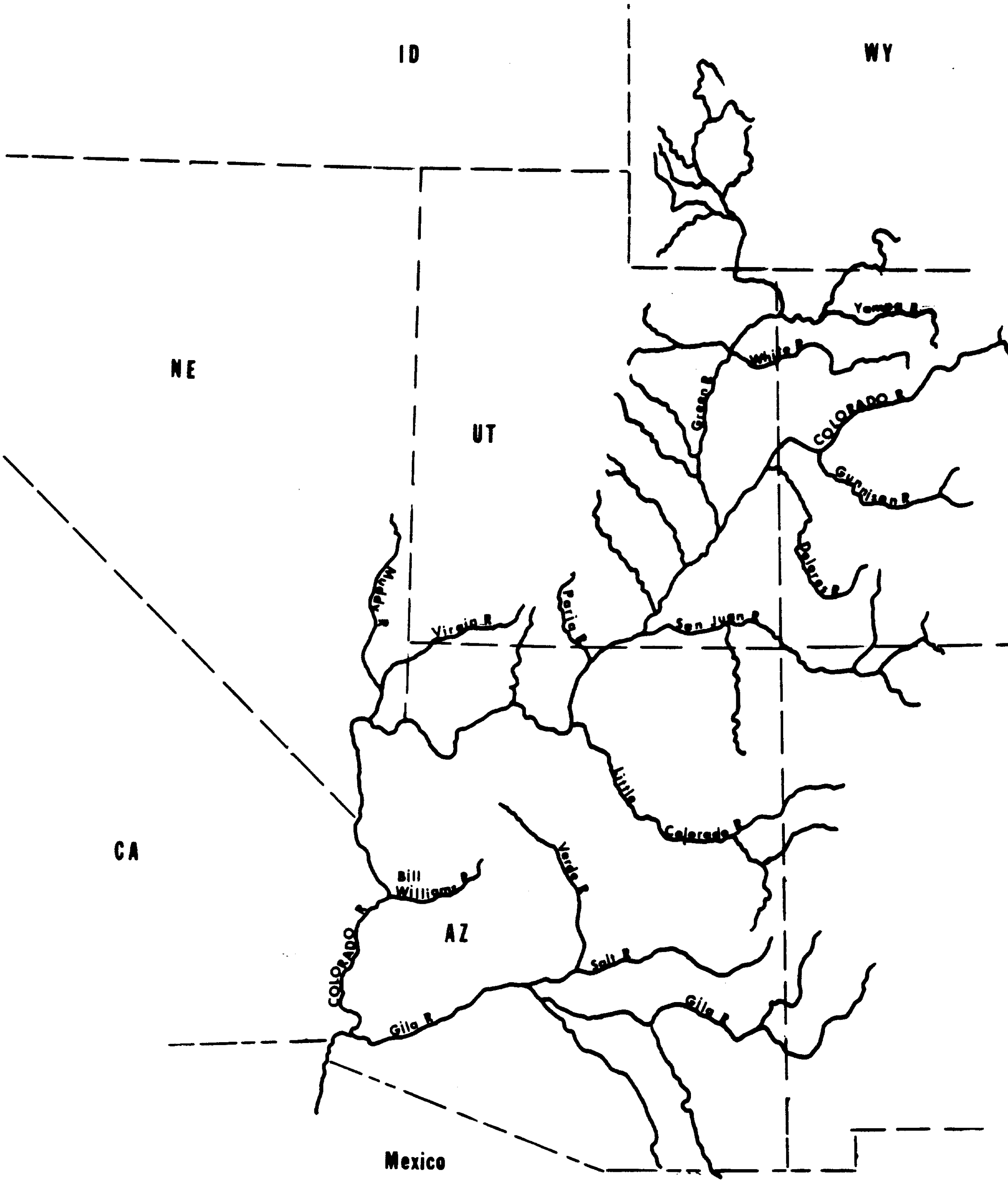


Figure 1

Colorado River and its major tributaries

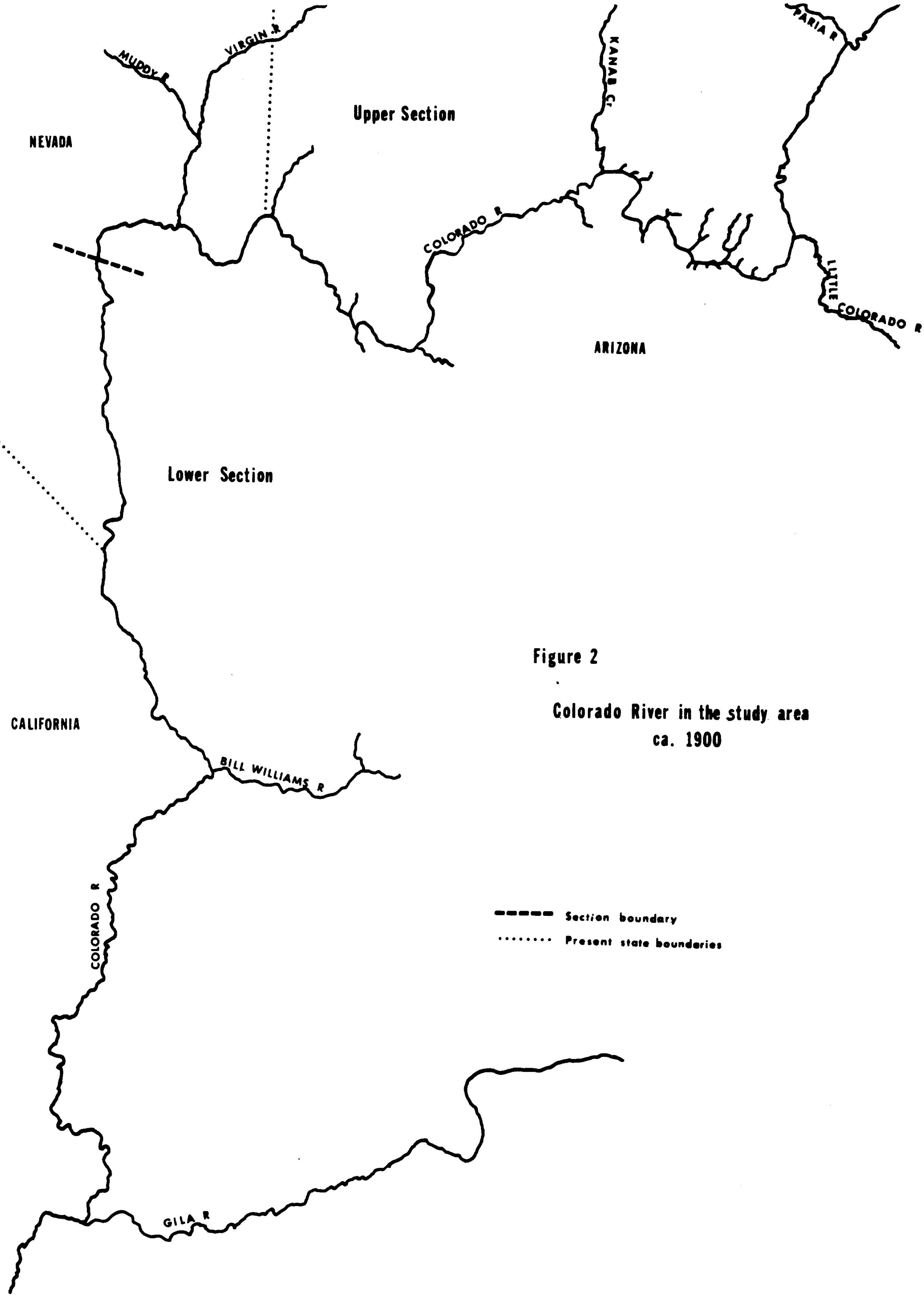


Figure 2

Colorado River in the study area
ca. 1900

Below the Black Canyon the gradient lessened to 1.8 feet/mile (Dill 1944). The land opened into broad flat valleys with small, north-south tending mountain ranges. The river was slower here, meandering across the desert plains on its way to the sea. The lower river had only two tributaries, the Bill Williams and Gila Rivers. After sporadic rains normally dry desert washes carried flood waters into the Colorado.

Flows in the river varied tremendously over the course of the year, reaching a peak in June as snow melt from the mountains reached the lower river. Flows declined sharply in August and remained low through February (Dill 1944) (fig. 3). Unusual flood flows in the early spring were not uncommon if winter rains were heavy. A 250,000 c.f.s. flow was recorded at Yuma in January 1916 (Dill 1944). The more usual spring flood flows were 86,000 c.f.s. to 100,000 c.f.s. at Lee Ferry (Carothers and Minckley 1980) with similar readings in the lower river. Late summer low water levels could be extremely low as evidenced by the 538 c.f.s. flow at Imperial Dam in August 1934 (USDI-USGS 1978). Table 1 contains some historic extreme flows from the Colorado.

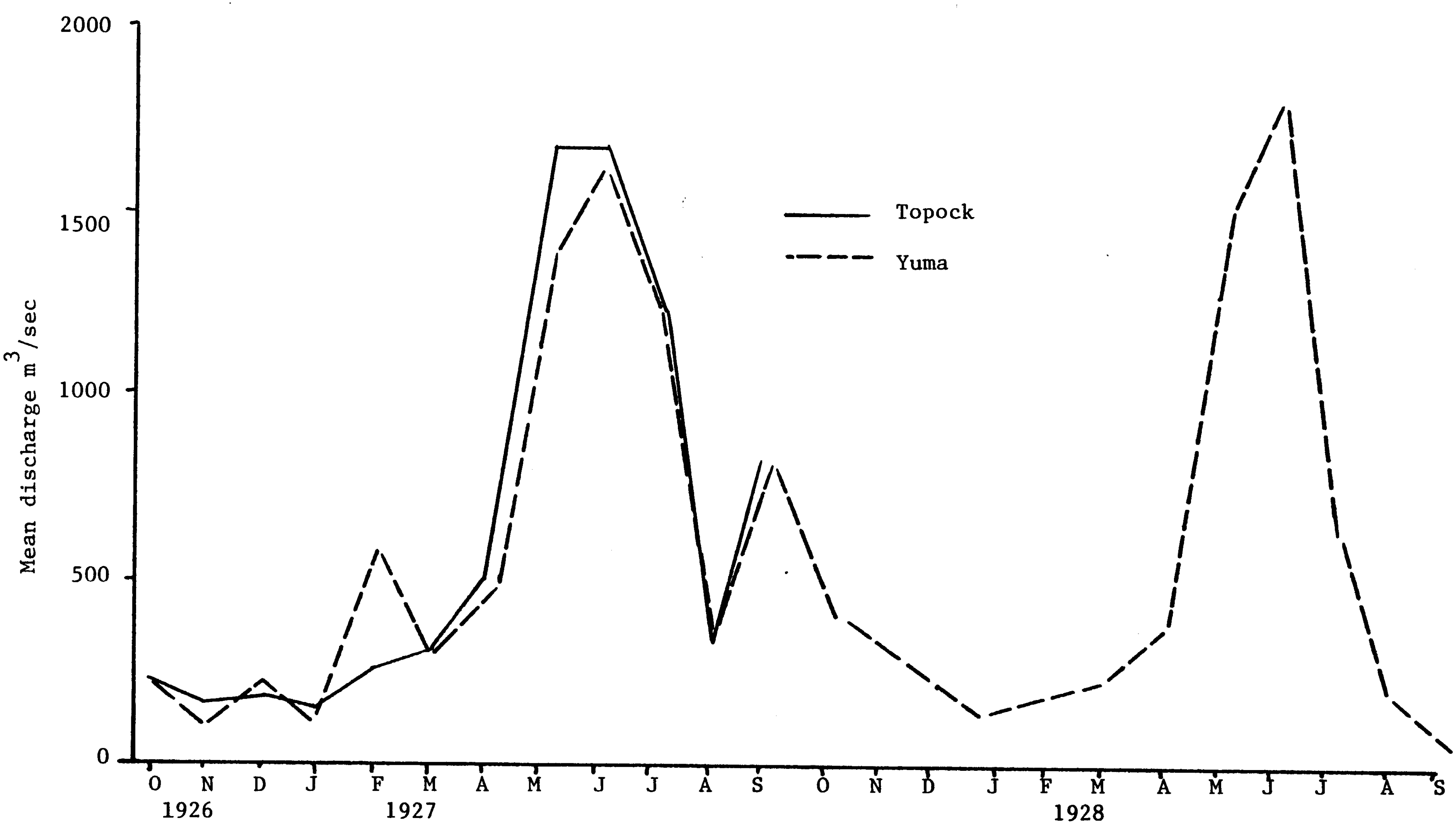


Figure 3
Mean discharge of the Colorado River at two points on the lower river prior to the construction of Hoover Dam. (from Howard 1929a cited in Saiki, Kennedy and Tash 1980)

Table 1. Extreme flows from the Colorado River

Grand Canyon	est. 300,000 c.f.s.	July 1884
	200,000 c.f.s.	1921
	121,000 c.f.s.	1927
	700 c.f.s.	Dec. 1914
Boulder Canyon	range 3000 - 150,000 c.f.s.	
Needles	est. 384,000 c.f.s.	1884
Imperial Dam	538 c.f.s.	August 1934
Yuma	250,000 c.f.s.	Jan. 1916
	18 c.f.s.	Aug. 1934

from Carothers and Minckley 1980
Dill 1944
USDI-USGS 1978

In its journey to the sea the Colorado picked up a vast quanity of silt. The arid climate, soft deposits, lack of terrestrial vegetative cover and the violent floods contributed to this silt load and made the Colorado the greatest silt carrier in the world (Dill 1944). At Lees Ferry 100 million tons of silt per year entered the lower river (USDI-NPS 1975). The silt load at Yuma, measured above the Gila River, was estimated at 500,000 tons per day and 138,000 acre feet per year (Dill 1944). Turbidities in the lower river were usually over 15,000 mg/l with occasional readings over 30,000 mg/l (Saiki, Kennedy and Tash 1980). As expected, the amount of silt carried varied with water flow (fig. 4 and 5). Silt was deposited in beds and banks during low flows and picked up again as flows increased.

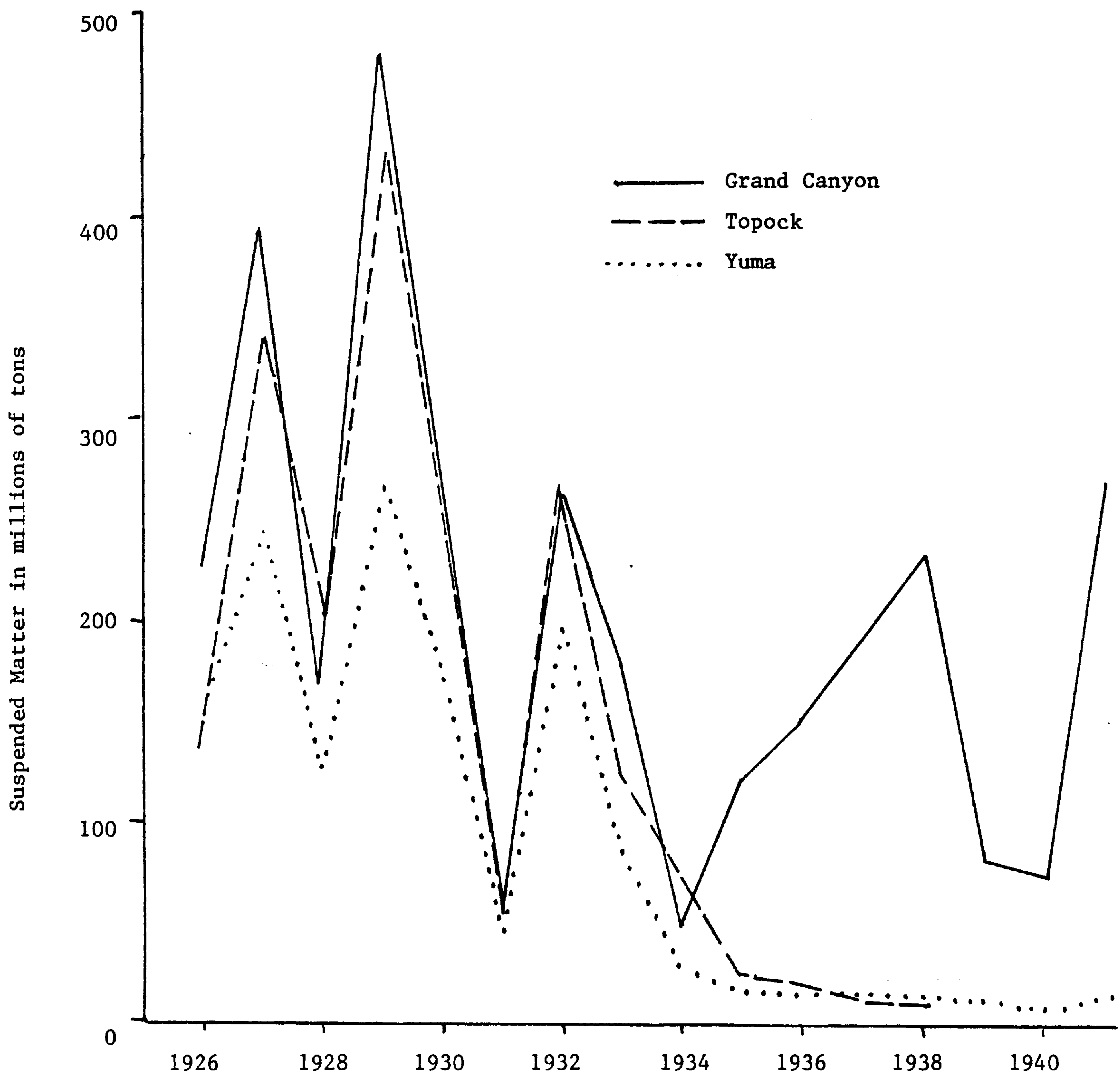


Figure 4.
Silt load of the Colorado River prior to and after the construction of Hoover Dam

(from Howard 1947 cited in Saiki, Kennedy and Tash 1980)

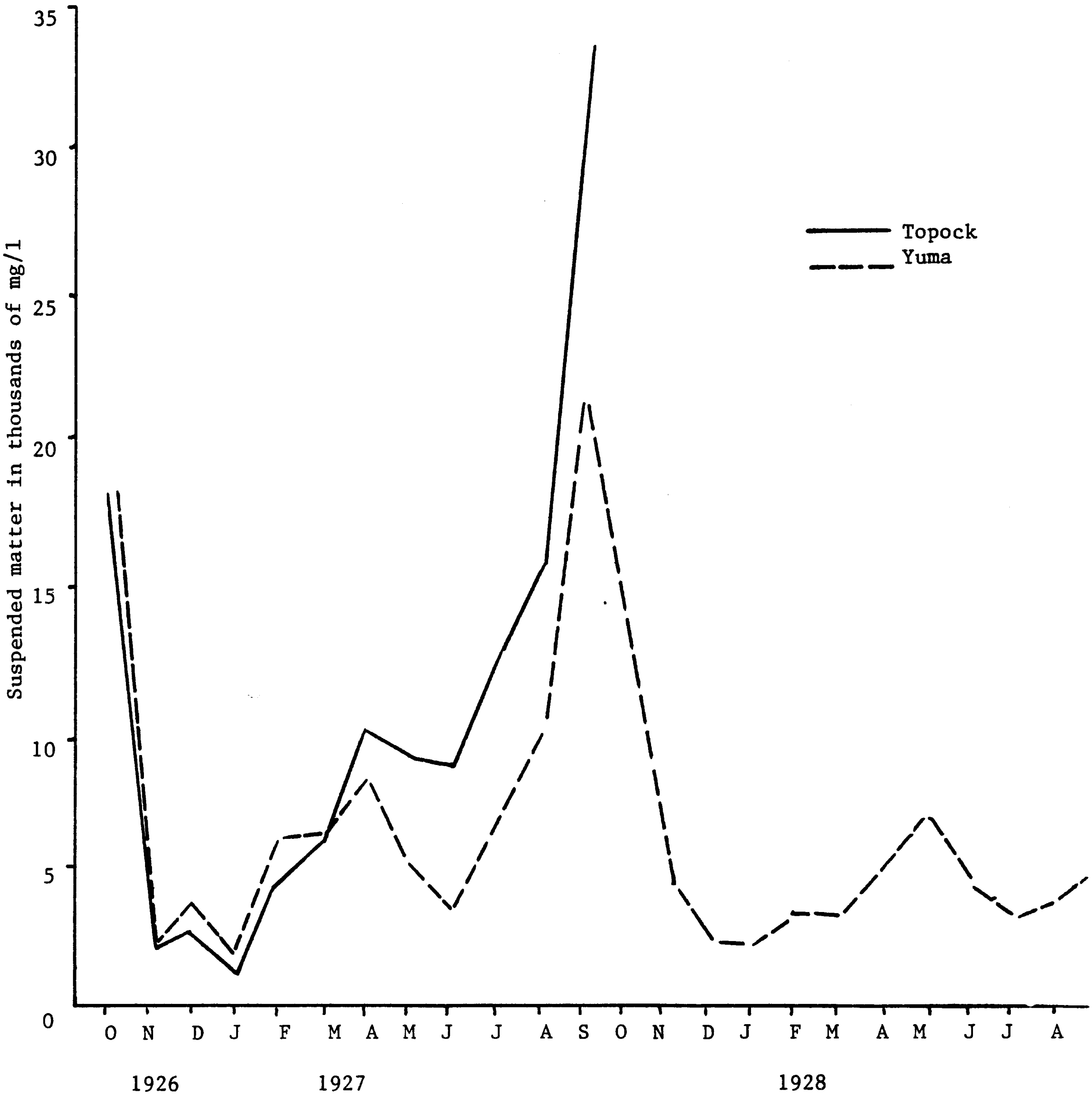


Figure 5
Suspended matter at two points on the lower Colorado River prior to to the construction of Hoover Dam. (from Howard 1929b cited in Saiki, Kennedy and Tash 1980)

There were a number of saline springs and seeps that fed into the Colorado along its length. The resultant salinities were inversely proportional to total river flow - the result of dilution (fig. 6) (Saiki, Kennedy and Tash 1980).

In the upper river (Grand Canyon area) water temperatures ranged from 29.5°C (85.1°F) in the summer to nearly 0°C (32°F) in the winter (Cole and Kubly 1976). Extremes for the lower river ranged from 32°C (90°F) to 4°C (40°F) with more average temperatures between 25°C (80°F) and 10°C (50°F) (Dill 1944). Winter temperatures were higher in the lower river due to the higher winter insolation this area received.

Temperatures reached a maximum in July and August with minimums in January. Figure 7 shows the temperature regime for three sites on the lower river.

Aquatic Habitats

There were three principle habitat types in the Colorado River, the main channel, tributary streams and backwaters.

The mainstem Colorado through the Grand Canyon consisted of a series of rapids, deep pools and side eddies. Terraces and beaches were formed when the river flow was low and slow enough to deposit sediment. These terraces were transitory, often lasting only until the next high water period. The yearly floods had a drastic effect on this habitat, removing

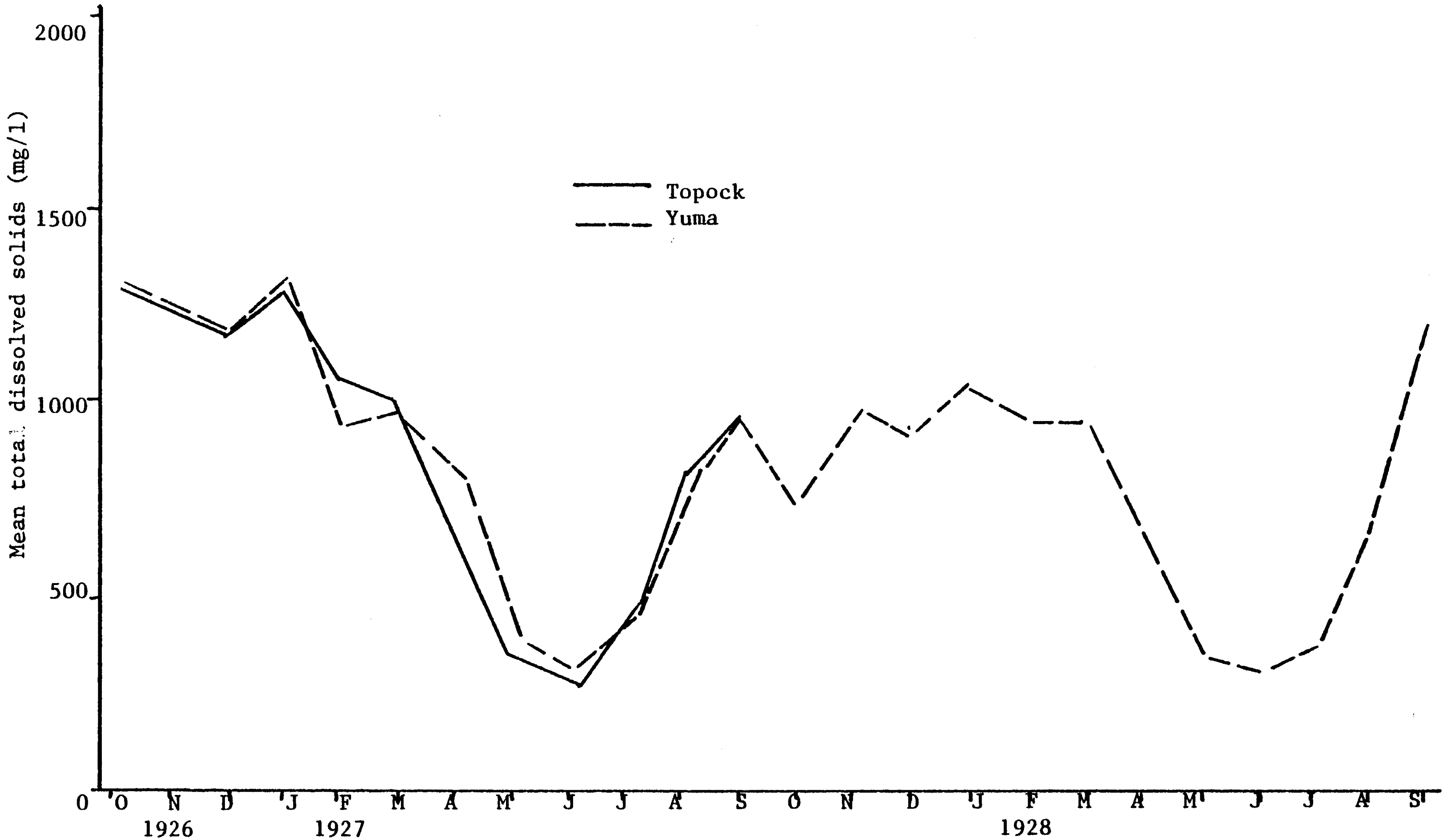


Figure 6
Mean total dissolved solids in the lower Colorado River, 1926-1929

(from Howard 1929a cited in Saiki, Kennedy and Tash 1980)

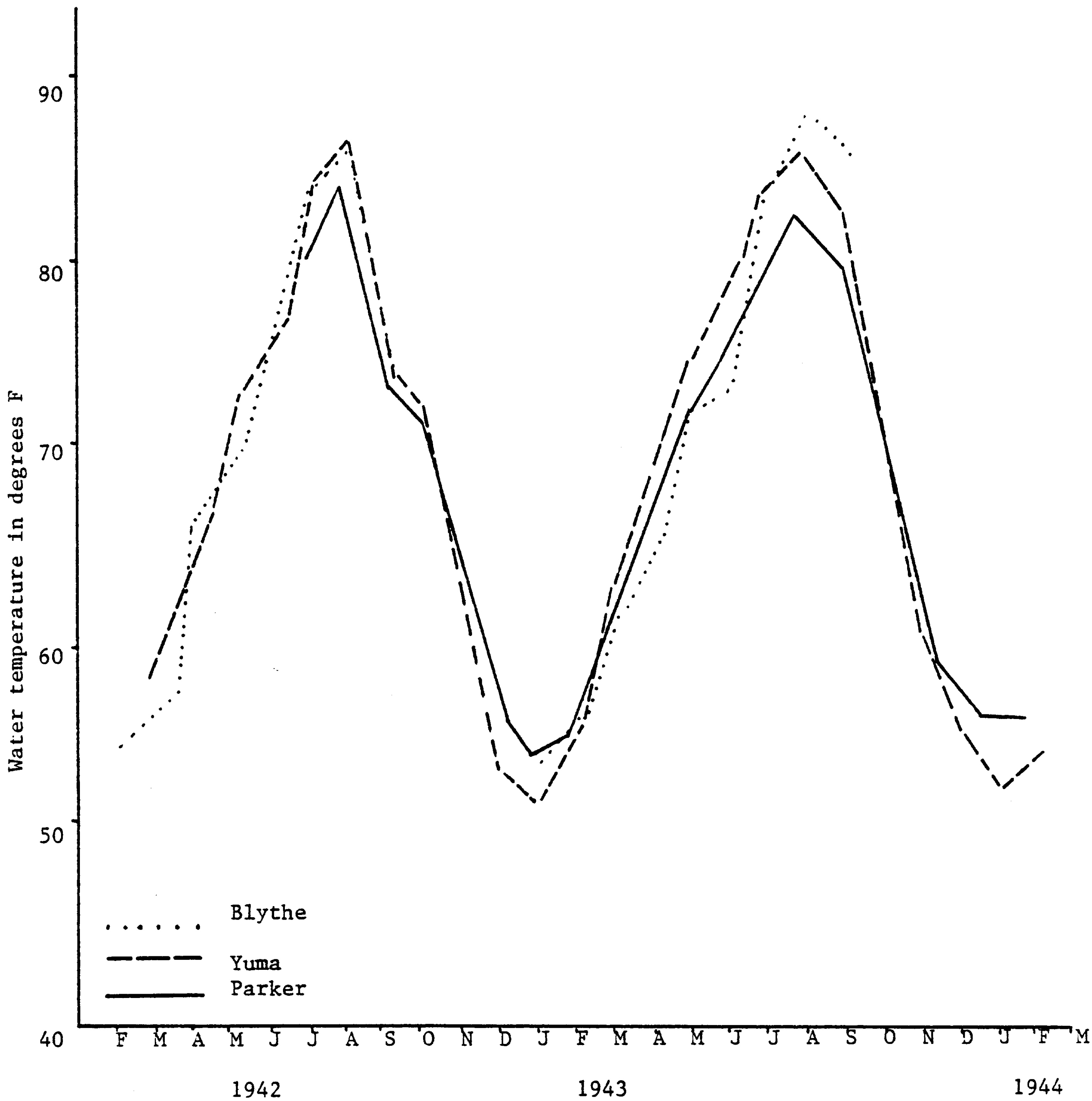


Figure 7
Mean monthly water temperatures at three points on the Colorado River. (from Dill 1944)

newly established plant and invertebrate populations. Until the construction of Glen Canyon Dam in 1963 controlled the water levels of the river, there was little riparian development through the Canyon (Turner and Karpiscak 1980). In contrast, the lower stretch of the river possessed a well developed riparian zone in its wide floodplain.

There was very little aquatic vegetation present in the mainstem. The high turbidity effectively curtailed light penetration, and the shifting substrate did not provide a stable anchorage for plants. Studies in Glen Canyon prior to dam construction (Dibble 1958) indicated that few, if any, aquatic plants could be found in the mainstem. Later work in the Grand Canyon (Carothers and Minckley 1980) found only Cladophora spp. widespread in the river, with Zannichellia palustris growing in the mainstem near Lees Ferry. In the lower river, it is reasonable to assume that few aquatic plants were present. Even today, rooted aquatics are essentially absent or sparse in most of the lower river (Minckley 1979).

Like other large erosive rivers, the Colorado lacked a well developed invertebrate fauna (Hynes 1972). The fauna could be characterized as non-diverse but locally abundant. The mainstem Colorado in Glen Canyon supported about 20 species of aquatic insects (Table 2) (Dibble 1958) as compared to a total of 91 species collected in the tributaries. Aquatic oligochaetes were also present. As it is now, the invertebrate fauna of the lower river was probably dominated by chironomids and oligochaete worms with a few dragonflies, snails (Physa spp. or Lymnaea spp.) and native clams (Sphaeridae) (Minckley 1979).

Table 2. Invertebrate Species from the Colorado River in Glen Canyon

Ephemeroptera

Heptagenia elegantula
Baetis sp.
Traverella albertana
Tricorythodes sp.

Odonata

Gomphus intricatus
Argia emma

Hemiptera

Gerris remigis
Microvelia americana

Megaloptera

Corydalus spp.

Trichoptera

Potamyia spp.
Brachycentrus spp.

Diptera

Simulium spp.
Empidae spp.
Tendipedidae midges (several species)

The Colorado possessed two types of tributaries. Large tributaries - the Gila and Bill Williams Rivers, and to some extent the Virgin, Muddy and Little Colorado Rivers - possessed physical and biological characteristics similar to the mainstem Colorado. The smaller creeks and streams of the Grand Canyon had quite different characteristics (Cole and Kubly 1976; Carothers and Minckley 1980). These tributary streams often contained a wider variety of aquatic and emergent plants than the mainstem. Although still subject to periodic flooding, the habitat was stable enough to support a riparian flora, as well as cattails (*Typha* spp.), sedges (*Scirpus* spp.), rushes (*Juncus* spp.) and giant reed (*Phragmites* spp.). Charophytes, pondweeds (*Potamogeton* and *Zannichellia*) and filamentous algae were also present in tributaries (Carothers and Minckley 1980).

Small tributaries also contained a much wider variety of aquatic invertebrates (Dibble 1958; Carothers and Minckley 1980).

Because of their higher productivity, tributaries supplied the mainstem with organic materials and invertebrate drift to sustain the riverine biota. Large debris, branches and logs, carried into the river by floods provided a substrate for periphyton flora and fauna to develop (Minckley 1979). Tributaries also provided sheltered nursery or resting areas for fish.

In the lower river, the backwater lakes and marshes were the analogs of the canyon tributaries. While tributaries were permanent features, backwaters were transitory, lasting at most 50-75 years (Ohmart, Deason and Freeland 1975). In these quiet, protected areas, the water was clearer and the substrate was stable enough to permit the growth of plants. Beds of cattails, sedges, Potamogeton spp., Zanichellia spp., Najas spp., and Chara spp. lined banks and shallows, with filamentous algae forming submerged mats. The soft, stable substrate harbored chironomids and other burrowing insect larvae, oligochaete worms and native clams. Snails, dragonflies, beetles, true bugs, and other insects inhabited the plant beds. Like the upper river tributaries, these backwaters exported organic material to the mainstem. Backwaters also provided feeding, resting and nursery areas for fish.

The Colorado River possessed a unique fish fauna found in no other river system (Table 3). While some species were extremely localized in occurrence, restricted to a particular river like the Moapa dace or Virgin River spinedace or to a particular habitat like the speckled dace (tributaries) and Gila topminnow (backwaters and springs), the remaining species were adapted to the river channel and moved throughout the system with ease (Minckley 1979). Nor were these unique species rare or scarce. Early settlers spoke of "runs" of Colorado River squawfish so abundant they could be pitchforked out of the river. The razorback sucker was equally abundant and with bonytail chubs very common. The machete and striped mullet, two marine species, were abundant in the area around Yuma.

Table 3. Native Fish Species of the Colorado River and Associated Tributaries

Elopiformes	
Elops affinis	machete
Cyprinidae	
Gila cypha	humpback chub
Gila elegans	bonytail chub
Gila robusta	roundtail chub
* Lepidomeda mollispinis	Virgin River spinedace
* Moapa coriacea	Moapa dace
* Plagopterus argentissimus	woundfin
Ptychocheilus lucius	Colorado River squawfish
Rhinichthys osculus	speckled dace
Catostomidae	
* Catostomus clarki	Gila sucker
Catostomus discobolus	bluehead mtn. sucker
Catostomus latipinnis	flannelmouth sucker
Xyrauchen texanus	razorback sucker
Cyprinodontidae	
Cyprinodon macularius	desert pupfish
Poeciliidae	
* Poeciliopsis occidentalis	Gila topminnow
Mugilidae	
Mugil cephalus	striped mullet

* found in tributary rivers to the Colorado.

The Influence of Man

The earliest people to utilize the Colorado River were Indian farmers and hunters. They constructed simple gravity fed diversion works to water their fields and fished in the river (Dill 1944; Miller 1955; USDI-Bur. Reclam. 1946). The Spanish explorers and missionaries built missions and utilized river water to irrigate their crops and, like the Indians, hunted the river wildlife. Their cattle and sheep grazed on the floodplains.

In 1848 the treaty of Guadalupe Hidalgo was signed, giving the Colorado River Basin to the United States. Crossings at Needles and Yuma were heavily used by gold seekers heading for California after the gold strike of 1849. Forts, like the one at Yuma built in 1851, attracted settlers who farmed and grazed in the Colorado Valley.

The modern history of the Colorado River began when Thomas H. Blythe moved to the Palo Verde Valley in 1856 and began to irrigate his farm (Appendix 1). In 1877 he filed the first water use permit for the lower Colorado River (USDI-Bur. Reclam. 1946). Other farmers constructed their diversion works along the river and began to farm the desert.

In 1892 the potential farmland of the Imperial Valley was discovered and plans were made to bring water from the Colorado to irrigate the fields. The Imperial canal was begun in 1895 by the California Development

Company and traversed portions of Mexico and the United States to the valley. Water began to flow through the canal in 1901. By September 1904, 8,000 people lived in the valley and 700 miles of drains had been constructed to irrigate 75,000 acres of cropland (Ohmart, Deason and Burke 1975).

Farming along the Colorado was a risky proposition. The river channel changed locations continually and the heavy sediment load silted up diversion works. Water levels were unreliable, flooding fields in the spring and nearly drying completely by fall. Water shortages in dry years left crops withering in the fields.

Floods wreaked havoc on man's designs and plans. In 1905 the river broke through a cut 4 miles below the international boundary and flowed northwest into the Imperial Valley. For 16 months the entire flow of the Colorado inundated farms, roads, and railways and transformed the Salton Sink into the Salton Sea. When the river was finally diverted back to its original course in 1907, the Salton Sea was 76 feet deep, 488 square miles in area and covered 30,000 acres of cropland (USDI-Bur. Reclam. 1946).

To protect riverside developments from yearly floods, 150 miles of levees were constructed and maintained. Breaks in the levees were not uncommon. The Yuma project was flooded several times before the 1920's. In 1922 a break in the Palo Verde Valley levee caused disasterous local flooding. Between 1906 and 1924, $10.25 million was spent on levee construction and maintenance. The 100,000 acre-feet of silt deposited in the delta lifted the river bed higher each year, necessitating that the levees be raised to maintain flood protection. In addition, the silt clogged the canals resulting in high maintenance costs. Laguna Dam, completed in 1909 as a diversion structure, was filled with silt within 6 months of dam completion (Sykes 1937 cited in Ohmart, Deason, and Burke 1975).

Up to this point, man's impact on the river biota had been limited. Local disturbances for construction of diversion works had little impact unless a marsh or backwater was destroyed or modified. The riparian zone suffered greater impacts due to tree cutting for fuel and construction and clearing for agricultural purposes (Ohmart, Deason and Burke 1975).

In 1931 work was begun on a dam in the Black Canyon. Boulder Dam (now Hoover Dam) was completed in 1935, and its reservoir, Lake Mead, began to back up into the canyons cut by the Colorado. The new reservoir, which filled in 1941, reached 183 Km in length with a maximum depth of 180 m (Paulson, Baker and Deacon 1980).

Lake Mead, in striking contrast to the muddy Colorado, was clear. The great sediment load was dropped at the head of the lake. The small populations of aquatic and emergent plants that existed in the river's side canyons were lost as the water rose. In the new coves and bays these plants could establish populations. Patches of cattails, sedges and giant reed became established in the heads of coves, with pondweeds and other aquatics becoming established in the shallow water. The rising water levels of the first 5 to 6 years tended to drown out the new plant populations, resulting in very sparse distributions.

Dipteran larvae and oligochaete worms continued to dominate the invertebrate fauna. Other still-water invertebrates from upstream tributaries invaded and colonized the shallows. Water boatmen, backswimmers and dragonflies were the only insects in any abundance, aside from chironomids (Jonez and Sumner 1954). Crayfish (Procamberus spp.) became established from bait releases and Corbicula manilensis was established by the early 1960's.

Prior to the closing of Hoover Dam, the segment of the Colorado that was to become Lake Mead possessed the river's unique fish fauna. Colorado River squawfish, bonytail chubs, razorback suckers, and flannelmouth suckers inhabited the mainstem. Woundfin, Moapa dace, Virgin River spinedace and bluehead mountain suckers inhabited the Virgin and Moapa Rivers.

In 1935 largemouth bass, sunfish, and channel catfish were introduced into the new reservoir to provide a sport fishery. The combination of competition with introduced fish species, including the previously introduced carp, and habitat loss resulted in the virtual elimination of native fish from the reservoir. Woundfin, Moapa dace and Virgin River spinedace were never seen in the reservoir. Bluehead mountain suckers were seen in the Overton Arm tributaries as late as 1963. Of the mainstream fish, only razorback suckers are known to persist. Squawfish disappeared by the mid 1950's and the last verified bonytail chub was seen in 1967. Flannelmouth suckers still exist up stream from Lake Mead.

In addition to the upstream changes caused by Hoover Dam, the tailrace system was markedly different from the original river. Drawn from deep in Lake Mead, the water released from the dam is clear and cold (figs. 4 and 8). The silt free water picked up previously deposited silt and sand below the dam and carried it downstream. Within a few years, a 25 mile stretch through the Black Canyon had been transformed into a clear, cold, gravel and rock bottomed stream suitable for trout. <u>Cladophora</u> spp. grew abundantly on the rocks and gravel and provided the basis for the development of a new invertebrate fauna. Mayfly nymphs were very abundant, as were caddisfly larvae and chironomid larvae and pupae. Snails (<u>Lymnaea</u> spp.), were periodically abundant with a few plecopterans and aquatic beetles also present. Abundant oligochaetes and zooplankton added to the fauna (Jonez and Sumner 1954).

In 1941 100,000 gammarid amphipods were stocked at Willow Beach to add to the available trout forage (Moffett 1942). Rainbow trout were first stocked in the river in 1935 and in 1961 a federal trout hatchery was built at Willow Beach to supply the lower river.

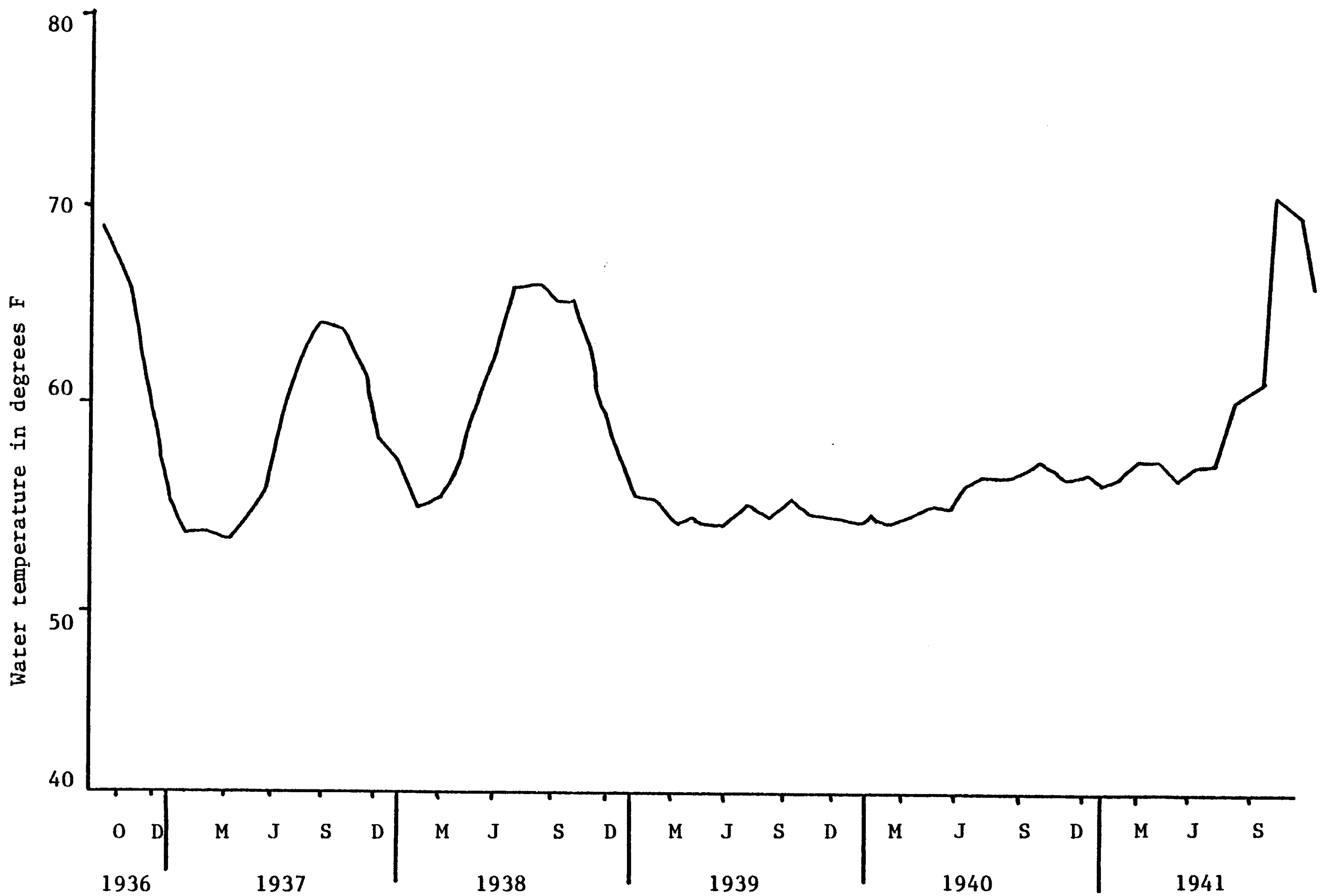


Figure 8
Monthly average water temperatures from the Colorado River at Willow Beach prior to and after the filling of Lake Mead. (from Moffett 1942)

The original riverine, emergent flora persisted in shallows and on banksides in the Black Canyon and open basins downstream. Water in the lower river (to about 50 miles below Hoover Dam) was still fairly clear but was warmer than water in the Black Canyon. *Cladophora* spp., *Chara* spp., and *Potamogeton* spp., were present in this area, with chironomids and oligochaetes the dominant invertebrates. Fish consisted of the large native minnows and suckers, carp, channel catfish and largemouth bass. Backwaters or oxbow lakes were formed by the river's meandering course.

The second large dam on the Colorado was begun in 1934, just below the confluence of the Colorado and Bill Williams Rivers. Parker Dam was completed in 1938 and its reservoir, Lake Havasu, flooded an open, shallow basin where the river had been flanked by backwater lakes and lined by a well developed riparian community of cottonwoods, willows and mesquite. The river channel inundated by Lake Havasu was biologically similar to that inundated to become Lake Mead. The shifting silt and sand substrate provided minimal habitat for aquatic plants or insects. Chironomids and oligochaetes again dominated the fauna with few stands of plants developing in eddies and shallow areas. Colorado River squawfish, bonytail chubs and razorback suckers made up the native fish fauna. Carp, channel catfish and a few centrarchids were also present.

The marshes and backwater lakes provided a refuge for plants, invertebrates and fish. The quiet water and stable substrate permitted abundant growth of emergent plants such as cattails, sedges and giant reed and submerged species Potamogeton pectinatus, Najas marina and filamentous green and blue green algae. Weed and bottom dwelling odonates, hemipterans, coleopterans, dipterans, oligochaetes, snails, native clams and zooplankton made up the invertebrate fauna. These backwater areas were used as nursery, refuge and feeding areas by fish in the river.

The variety of plant and invertebrate species present prior to the construction of Parker Dam continued in the new reservoir. Due to certain operating constraints, Lake Havasu's water level stays nearly constant, enabling aquatic vegetation to become established in the clear coves. Extensive marshes began to form at the Bill Williams delta and at the head of the lake, where the silt and sand carried out of the reach below Hoover Dam was deposited in the slack water.

Bluegills and largemouth bass were introduced into Lake Havasu in 1939 (USDI-USFWS 1979) and along with channel catfish, formed the basis of a warm water fishery. Carp became extremely abundant throughout the reservoir. Native fish populations declined. Squawfish were rare by the late 1930's and eliminated by the late 1940's. Bonytail chubs persisted into the mid 1950's. Only razorback suckers have persisted in Havasu but they are rare in the lake.

Because of Lake Havasu's shallow depth, the tailrace of Parker Dam is not cold enough to provide a trout fishery. The water is, however, silt free and has removed the silt and sand from the tailrace. Aquatic plants and filter-feeding invertebrates are abundant in this area. Potamogeton pectinatus, Ceratophyllum demersum, Chara spp. and other algae species are present in the channel and quiet eddies. Simuliid and tabanid dipterans, hydrophylid beetles, baetid ephemeropterans, and the usual chironomids and oligochaetes form the benthic fauna. Introduced snails, Radix spp. and Asiatic clams (Corbicula sp.) later became abundant (Minckley 1979).

Imperial Dam was completed in 1938 near Yuma. This small dam was designed as a water diversion facility. Imperial Reservoir flooded backwaters and channel much like that found at the site of Lake Havasu. The heavy sediment load at Imperial Dam (fig. 4) caused rapid sedimentation of the reservoir, forming marshes and shallow vegetated areas with abundant plant and invertebrate populations. The only native fish that remained in this area were the two marine species, the machete and striped millet.

The sediment load of the Colorado was the cause of great concern in the years following the construction of Hoover, Parker and Imperial Dams. When the Colorado tumbled out of the Grand Canyon into the quiet waters of Lake Mead, the great sediment load was deposited at the head of the lake. The water released from Hoover Dam was clear and sediment free.

This water picked up previously deposited sediment from the reach below the dam, scouring and deepening the channel (USBR n.d.). The water carried this sediment to the head of Lake Havasu, where in the quiet stretch of Topock Gorge, it was redeposited. The aggrading area continued to move up river and eventually parts of Needles, California began to be inundated. Similar patterns of scouring and aggrading were present below Parker and Imperial Dams.

Legislation was enacted in 1946 to permit the Bureau of Reclamation (now the Water and Power Resources Service) to develop a comprehensive river management plan under the authority of the Colorado River Front Work and Levee System Act. The initial goal of the plan was to control flooding caused by channel meandering and silt deposition (USBR nd.). Channelization of the stream bed and riprapping banks were to be the primary techniques. Work has expanded to include water salvage, control of water movement and bank erosion (Ohmart, Deason and Burke 1975).

In 1949 the newly constructed dredge "The Colorado" began to channelize the reach between Needles and Topock. Another dredge "Little Colorado" was acquired in 1957 and a third dredge "Gila" began operations at Laguna in 1963. A smaller, unnamed dredge was built in the 1950's. Appendix 2 gives a chronology of dredging projects in the lower river.

Dredging, channelization and bank modifications had adverse impacts on the aquatic habitats of the Colorado River. Eddies, shallows and holes as well as other low current areas were eliminated where the channel was deepened and straightened. Since these areas provided habitat for plants, invertebrates and fish, these populations were either eliminated or extremely reduced. Benthic diatoms and filamentous algae grew on any available hard surface with sparse populations of native clams, oligochaetes and chironomids in the shifting sand substrate. Only the current-loving red shiner, (Notropis lutrensis), maintained populations in the channelized reaches (Minckley 1979).

Backwaters and marshes were cut off from the river by channelization, eliminating their value to the riverine biota. These areas were either filled in during construction, or if they remained, dried up when the water table dropped in the newly deepened channel. Bank armoring restricted water flow into and out of surviving backwaters. Limited water exchange and the desert's high evaporation rate resulted in declining water quality. Eventually, these backwaters would become uninhabitable by most plant, invertebrate and fish species. Of the remaining backwaters of the Colorado River, many are already suffering from water quality degradation that will eventually eliminate them as viable aquatic habitat.

While man's physical activities were making their mark on the Colorado River, another man-induced change was occurring - the establishment of exotic plants, invertebrates, and fishes. Tamarix replaced native riparian vegetation in disturbed areas. Species of Myriophyllum spp.

became established in quiet backwaters and lakes, but for the most part, the native plant species remained dominant.

Intentional releases of gammarid amphipods and fresh water shrimp (Palaeomonetes paludosus) by river managers were designed to provide forage for sport fish, while fishermen were responsible for the introduction of crayfish to the system. These invertebrate groups do contribute to the food resources available to fish. The same cannot be said for the Asiatic clam, Corbicula manilensis (also known as C. fluminea). First discovered in North America in 1938 in the Columbia River in Washington, it rapidly spread throughout the west. By the late 1940's it was a pest in California irrigation systems and established in the lower Colorado, reaching Lake Mead in 1962. While some use of Asiatic clams is made by bluegill, channel catfish and flathead catfish, clams are underutilized as a food resource.

The most profound change in the biota of the river was the introduction of a wide variety of non native fish species. Between the late 1800's and 1976, over 60 species of fish were introduced to the Colorado River (USDI-USFWS 1979). As new environments and habitats were created in the river, game and forage fish species were introduced in to provide the basis for developing recreational fisheries (Table 4). Nationally recognized fisheries developed for largemouth bass in Lake Mead, rainbow trout below Hoover and Glen Canyon Dams and, most recently striped bass in the lower river and Lake Mead.

Table 4. Date of first introduction of major exotic game and forage fish to the Colorado River

Species	Date
Ascipenseridae	
Ascipenser transmontanus (White sturgeon)	1967
Clupeidae	
Alosa sapidissima (American shad)	1884
Dorosoma petenense (Threadfin shad)	1954
Salmonidae	
Oncorhynchus kisutch (Coho salmon)	1966
Oncorhynchus nerka (Kokanee salmon)	1962
Salmo clarki (Cutthroat trout)	1925
Salmo gairdneri (Rainbow trout)	1922
Salmo trutta (Brown trout)	1924
Salvelinus fontinalis (Brook trout)	1920
Cyprinidae	
Cyprinus carpio (Carp)	1881-91
Notemigonus crysoleucas (Golden shiner)	1950
Notropis lutrensis (Plains red shiner)	1955
Pimephales promelas (Fathead minnow)	1958
Ictaluridae	
Ictalurus natalis (Yellow bullhead)	1970
Ictalurus punctatus (Channel catfish)	1892-93
Pylodictis olivaris (Flathead catfish)	1962
Percichthyidae	
Morone chrysops (White bass)	1968
Morone saxatilis (Striped bass)	1959
Centrarchidae	
Lepomis cyanellus (Green sunfish)	1940
Lepomis macrochirus (Bluegill sunfish)	1936
Lepomis microlophus (Redear sunfish)	1950
Micropterus dolomieui (Smallmouth bass)	1950
Micropterus salmoides (Largemouth bass)	1935
Pomoxis nigromaculatus (Black crappie)	1975

While populations of exotic fish expanded, native fish of the Colorado declined in population. This was especially true for the "big river" fish - squawfish, bonytail chub, humpback chub, and razorback sucker. One hypothesis (Minckley 1979) states that this decline was primarily the result of predation on eggs and young of the natives by introduced species. Loss of suitable habitat has been given as another contributing factor.

The last major impoundment on the lower river filled in May 1951. Lake Mohave formed behind Davis Dam and reached 67 miles to the tailrace of Hoover Dam. The new reservoir was composed of two sections. The upper 22 miles was in the steep walled Black Canyon. The river here was cold and clear, and contained the trout fishery developed since 1935. The river bed was gravel and rock, with deep holes scoured along the cliff edges. *Cladophora* spp. was the dominant plant, with small amounts of *Chara* spp. and *Potamogeton pectinatus*. Abundant mayfly, caddisfly, midge, aquatic worms, snails and amphipod populations provided forage for the trout. Water temperatures in this area were a fairly constant 11.5°C (55°F) Jonez and Sumner 1954).

The lower 45 miles of the reservoir went through three small canyons, spaced between open basins flanked with low hills. The river bed was sand and gravel, with a few deep holes in the canyon areas. The variable water releases from Hoover Dam combined with the unstable sandy river bed to create a meandering river channel. Chara spp., Potamogeton pectinatus and Zannichellia palustris were abundant on the gravel areas, with Cladophora spp. also common. The same invertebrates as found in the upper section were present. As a result of its shallow, meandering course, the river was warmer, reaching 20°C (69°F) at Bullhead City, 70 miles below Hoover.

The fish fauna of the area was a mixture of introduced game fish and native fish species. Rainbow trout were the most abundant and important game fish while channel catfish were of secondary importance. Carp were extremely abundant and two native fish, bonytail chubs and razorback suckers, were common. Colorado River squawfish, bluehead mountain suckers, and flannelmouth suckers were considered rare (Jonez and Sumner 1954).

After Lake Mohave filled, the trout-stream conditions were restricted to an area above Eldorado Canyon, 25 miles from Hoover Dam. The lower area became a clear (visibility over 20 feet), warm water lake with many bays and coves. Operating criteria resulted in severe (over 20 feet) water level fluctuations.

The slowing of the current and slight deepening in the upper reservoir fostered the growth of aquatic plants. Chara spp., Cladophora, Potamogeton pectinatus, and Zannichellia palustris were all extremely abundant. Plants in the lower reservoir were destroyed by the rising water levels and subsequent water level fluctuations made re-establishment difficult.

In 1954 only benthic algae was found in the lower reservoir. Invertebrate populations were also affected. Amphipods and snails disappeared from the lower reservoir area while mayflies and caddisflies vanished from the entire area, probably due to loss of breeding habitat. Midges and oligochaete worms became the dominant invertebrate groups.

Fish species composition also changed. Centrarchids became dominant in the lower reservoir, while trout remained dominant in the upper canyons. Carp continued to be extremely abundant. Of the native fish species, only the razorback sucker has persisted in any numbers. Bonytail chubs are extremely rare while Colorado River squawfish was extirpated in the early 1960's.

Lake Mohave is unique in that it is a warm water reservoir with a cold water inflow. Near Eldorado Landing, an interface between the warm and cold waters exists. The cold water flows underneath the warm surface water and travels downstream to Davis Dam (Paulson, Baker and Deacon 1980). This continual underflow provides for a deep water trout fishery in the lower reservoir.

The tailrace area of Davis Dam, formerly identical to the lower river section inundated by the reservoir, became a cold tailrace trout fishery. Rainbow trout supplanted largemouth bass as the dominant game fish. Invertebrates in the area include midges, dragonflies, damselflies, beetles and oligochaete worms. Amphipods and snails (*Lymnaea* spp.)

became established (Jonez and Sumner 1954). Native fish were eliminated from the tailrace area.

In addition to major dam construction, several smaller diversion dams were constructed along the lower Colorado. These structures included Headgate Rock Dam (1944), Morelos Dam (1950), Palo Verde Dam (1957), and Senator Wash Dam (1966). These structures had minimal impacts on existing riverine biota and physical conditions.

By 1960 the only stretch of the lower Colorado that remained unmodified was the river through the Grand Canyon. In 1964, Glen Canyon Dam was completed upstream of the Canyon. Impounding a reservoir with a surface area larger than Lake Mead, Glen Canyon began to have an impact on the river below.

The first major impact was the change in flow patterns. Prior to Glen Canyon, the highest flows were in May and June, decreasing throughout the year. Average daily flow was 2,486 m^3/sec with a median discharge of 210 m^3/sec. With Glen Canyon in operation, average flows fell to 830 m^3/sec with a median flow of 346 m^3/sec (Turner and Karpiscak 1980). Seasonal flow variations were replaced by daily and weekly variations. Extreme daily flows from Glen Canyon range from 28 to 764 m^3/sec with means of 130 m^3/sec to 566 m^3/sec (Carothers and Minckley 1980). Weekend flows from Glen Canyon are often much less than weekday flows - up to 80 percent - due to reduced power demands (Stone 1972). Figure 9 shows the change in flow patterns.

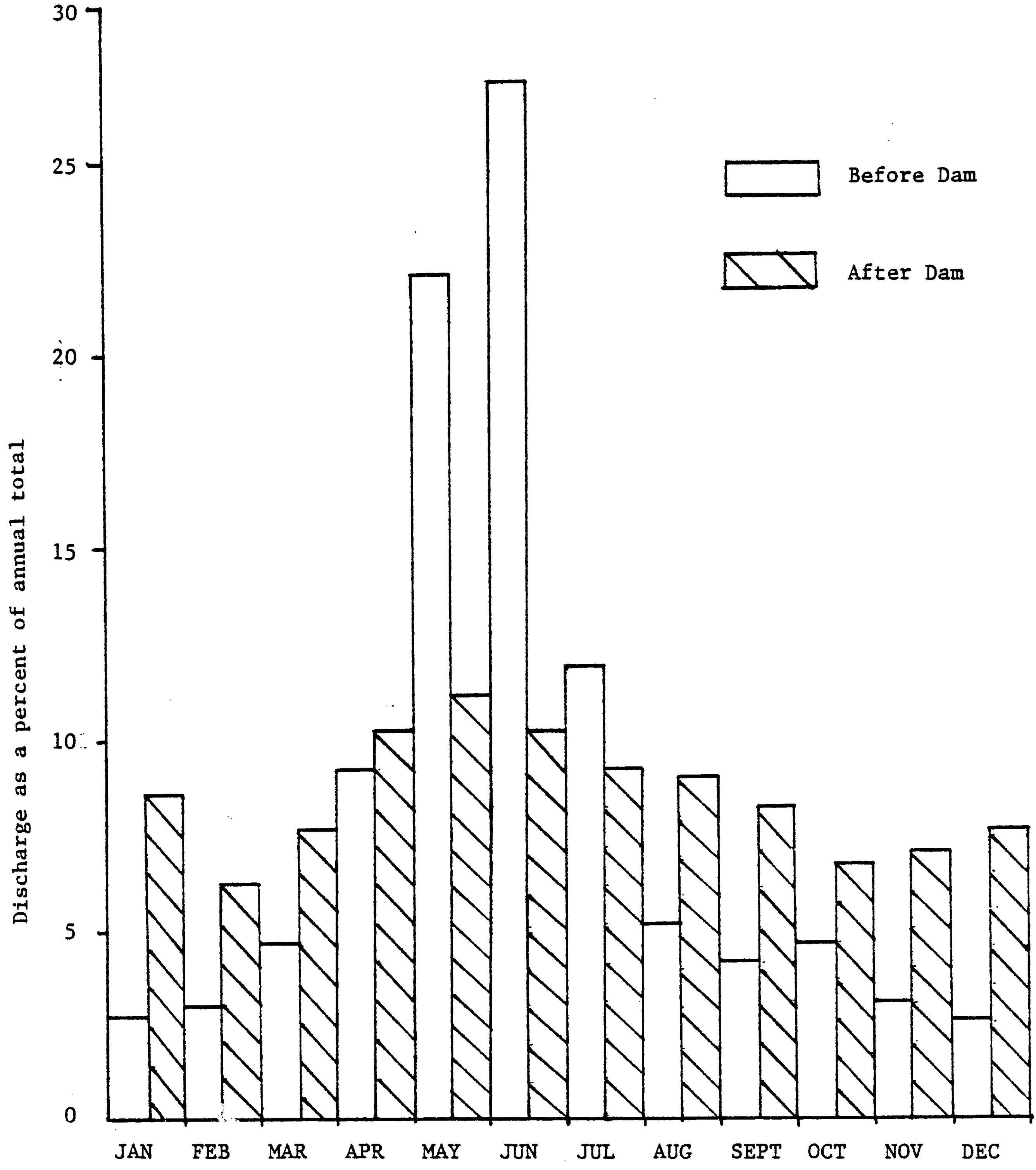


Figure 9 Monthly mean discharge of the Colorado River at Lee Ferry before and after the construction of Glen Canyon Dam 1901-1962.

from Turner and Karpiscak 1980

Prior to construction of this dam, the Colorado River carried 374 metric tons of sediment per day. Deposition of this material during low water periods formed beaches and terraces that would be eroded during high water. After the dam was built, the sediment load dropped dramatically from 1500 ppm to 7 ppm at Lees Ferry and 1250 ppm to 350 ppm at Bright Angel Creek (Carothers and Minckley 1980). The rise in turbidity is due to the erosion of pre-dam terraces and inputs from tributaries, especially the Little Colorado River. The National Park Service has addressed the problems of sedimentation and erosion in several reports (Howard and Dolan 1976; Laursen and Silverston 1976).

The most conspicuous feature of the erosion was the creation of another trout stream in the tailrace of Glen Canyon. Cladophora spp. covers rocks in this area, with Zannichellea palustris present near Lees Ferry. Amphipods, chironomids and oligochaetes are the major invertebrate groups.

The fish population of the region below Lees Ferry prior to the construction of Glen Canyon Dam was a mixture of native and introduced species. Colorado River squawfish and bonytail chubs were rare and may now have been eliminated. Humpback chubs, first described in 1944 from the Grand Canyon, persist in the river, especially near the Little Colorado River. Razorback suckers were uncommon, appearing only near the Paria River while flannelmouth and bluehead mountain suckers are still found throughout the system. Speckled dace are abundant in the tributaries (Carothers and Minckley 1980). Studies are presently being conducted on the tailwater habitat below Glen Canyon by the Arizona Department of Game and Fish.

Changes in river flows, sediment load, and temperature can be directly traced to operation of the storage reservoirs. However, the other water quality change is attributable to water use.

Although fluctuations in total dissolved solids have decreased since dam construction (figure 10), salinity of Colorado River water has been increasing due to saline, irrigation return flows (Skogerboe and Walker 1975; Slawson 1972). The salt load at Lees Ferry has increased 240 ppm (Iorns, Hembrec and Oakland 1965). Current concentrations at Hoover Dam range from 700-800 ppm with salinities increasing to Imperial Dam (Everett, Carlson and Quashu 1973). Salinities of 880 ppm below Parker and 1080 ppm below Imperial may be reached by 1990 (Valantine 1974). Backwaters are more saline than the mainstem due to poor circulation and high evaporation rates (Saiki, Kennedy and Tash 1980).

The Colorado River in figure 11 is greatly different from the river in figure 2. Highly regulated and modified to provide water for consumptive use, its physical, chemical, and biological faces have been permanently altered - and all within 100 years (Appendix 1). The present biological system is unstable and the river is changing rapidly as it adjusts to

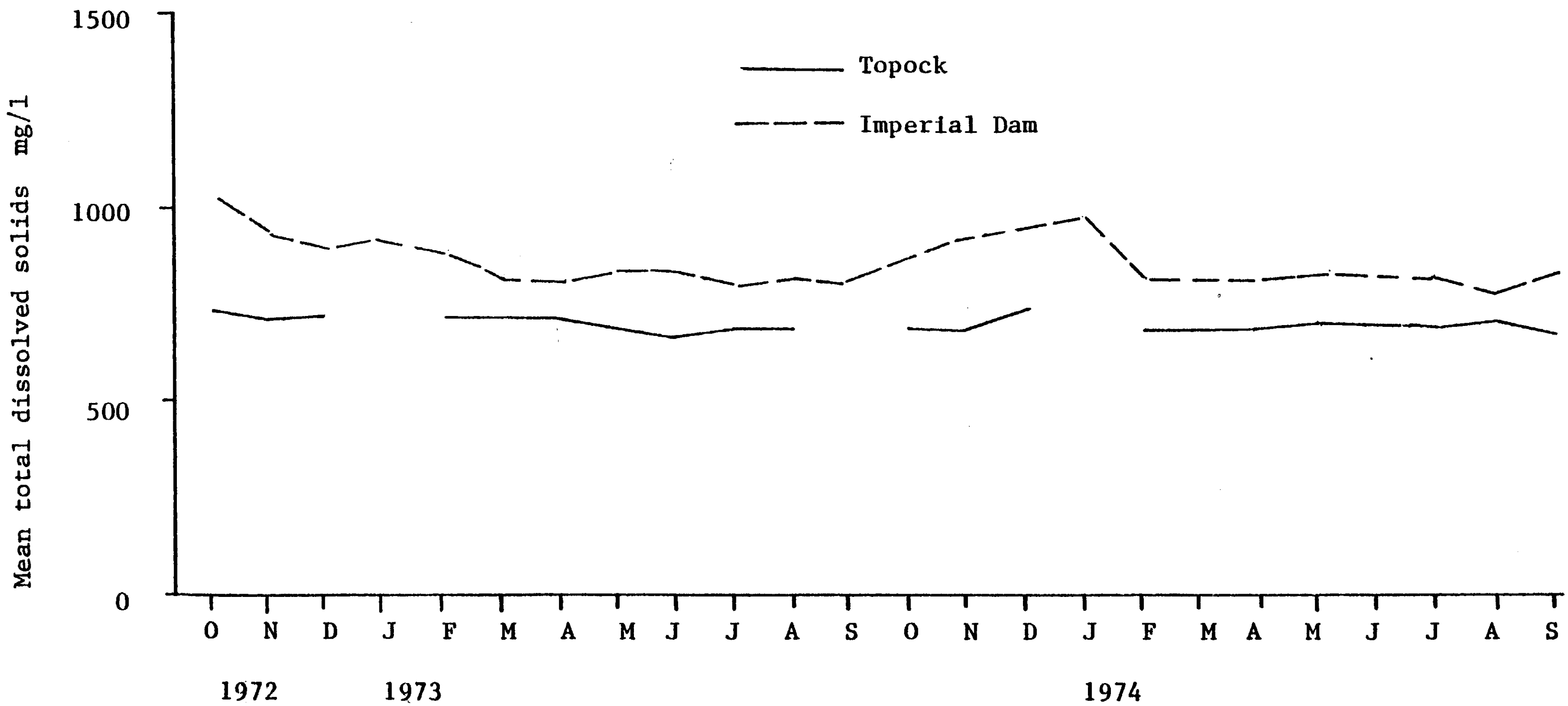


Figure 10
Mean total dissolved solids at two points on the lower Colorado River

USGS data 1974, 1975

(from Saiki, Kennedy and Tash 1980)

its new physical form. The river may come, at some future time, to a new equilibrium. However, changes in river operation may prevent an equilibrium from ever being reached.

II. Riverine Habitats - 1976

The Colorado River consists of several types of habitat--reservoirs, marshes, backwater lakes, tributaries, and modified and unmodified river channel (figure 11). These habitats contain different species and abundances of plants, invertebrates, and fish. Distributions of aquatic plants and invertebrate species are given in the appendices to this report (Appendices 3-10). The distribution of fishes in the Colorado River is given in the companion report Special Report on Distribution and Abundance of Fishes of the Lower Colorado River (USDI-USFWS 1979). This section will address each of the habitat types in terms of general physical characteristics, dominant plants and invertebrates, and the major species of fish present.

Reservoirs

There are three large reservoirs on the lower Colorado River - Lakes Mead, Mohave and Havasu. They are similar in that they are clear, warm water impoundments with abundant fish populations, but each has a unique character.

Lake Mead, the first and largest impoundment on the Colorado, was created in 1935 by the closure of Hoover Dam. Lake Mead is a 183 km long, warm water reservoir with a maximum depth of 180 m. and a mean depth of 55 m. The lake has an extremely irregular shoreline, and as a result, has many coves and bays (Paulson, Baker and Deacon 1980). The water is very clear throughout much of the lake, however fluctuations in lake level

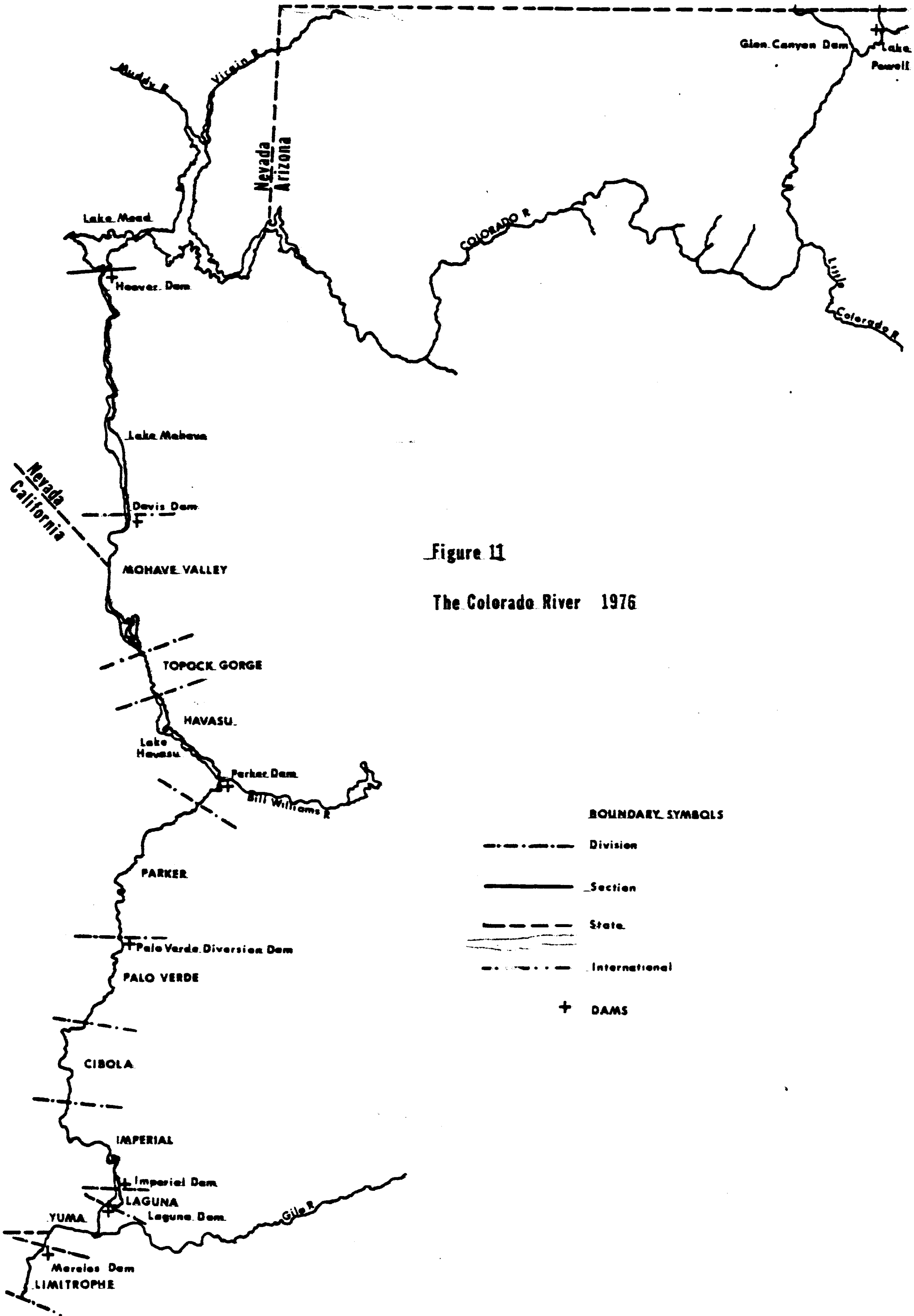


Figure 11

The Colorado River 1976

limit the zone of plant growth. Paulson, Baker and Deacon (1980) have been conducting extensive studies on the limnology of Lake Mead.

Najas marina, *Potamogeton pectinatus* and *Zannichellia palustris* are the major aquatic plant species found in the lake. The invertebrate fauna is dominated by chironomids and oligochaetes (Melancon 1977) with *Corbicula manilensis* forming extensive beds in areas of the reservoir. Coves with vegetation or other cover support a more diverse invertebrate fauna with crayfish, physid snails, odonates, several hemipterans (corixids, notonectids, belostomatids, gerrids) and simuliid larvae in addition to the chironomids and oligochaetes (McCall 1980B and others). Lake Mead has a diverse phytoplankton population with over 122 species of 76 genera recorded (Paulson, Baker and Deacon 1980). Zooplankton species of cladocerans, copepods and rotifers are abundant, especially in the lower basin, concurrent with highest phytoplankton production.

Lake Mead was a premier largemouth bass fishery in the 1940's and early 1950's. The introduction of threadfin shad for bass forage in 1954 restored the declining bass fishery (Roden 1978). However, the fishery declined again in the early 1960's, possibly related to the filling of Lake Powell upstream. In an effort to improve the fishery, rainbow trout were stocked for the first time in 1969. Striped bass were also introduced into Lake Mead in 1969 and reproducing populations developed rapidly. Striped bass now dominate the sport fishery in Mead. Centrarchids and catfish make up the balance of the catch. Trout have not attained the importance in Lake Mead they command in Lake Mohave, because the trout fishery in Mead is overshadowed by the striped bass.

Water released from Hoover Dam provides inflow for the next mainstem reservoirs - Lake Mohave. As a result of this cold water inflow, the upper section and deep areas of Lake Mohave support a substantial rainbow trout fishery.

Lake Mohave is a smaller reservoir than Lake Mead. While quite long (108 km), it is fairly shallow with a maximum depth of 42 m and a mean depth of 19.5 m (Paulson, Baker and Deacon 1980). Normal operating procedures cause fluctuations of 3-5 m in water level over the course of a year (Priscu 1978) and limits growth of aquatic plants.

Because the water released from Hoover Dam is drawn from deep in Lake Mead, it is nutrient rich. Lake Mohave is thus a more productive system than Lake Mead (Priscu 1978; Paulson, Baker and Deacon 1980). The shallow lake depth promotes more complete mixing, thus making nutrients more available to the surface. Lake Mead's greater depth and well developed stratification keeps nutrients below the photic zone.

Myriophyllum brasiliense, *Najas marina*, *Potamogeton pectinatus* and *Zannichellia palustris* are found in Lake Mohave, but are not abundant. Several species of algae are also present. Stands of cattails and sedges are found in some coves and shallows.

Chironomids, oligochaetes and Asiatic clams are the dominant invertebrates. Crayfish, odonates and other dipterans (tipulids, culicids and simuliids) are also present in the reservoir. Priscu (1978) recorded 85 species of phytoplankton.

Rainbow trout are extensively stocked in Lake Mohave and comprise the majority of the sport catch. Largemouth bass are the most important warmwater game fish, however there are indications that striped bass are now present in Lake Mohave (Arizona Department of Game and Fish data). If striped bass are present, they will probably become the most important warmwater game fish. Sunfish and channel catfish make up the balance of the sport fishery. Threadfin shad and carp are the most abundant nongame fish species.

The third reservoir on the Colorado is Lake Havasu. Created in 1938 as a desilting basin for the diversion canals carrying water to Los Angeles, 72.5 km long. Lake Havasu is broad and shallow with a maximum depth of 18 m (Minckley 1979). Lake Havasu has an irregular shoreline and because of operating constraints the water level remains stable - fluctuating less than 1 meter over the course of a year. The reservoir is subject to strong wind-mixing which hinders thermalcline development and has a warmwater tailrace as a result of releases from Parker Dam via surface penstocks. The release of epilimnetic water also results in Havasu having a lower surface water temperature than the other large reservoirs (Minckley 1979).

Lake Havasu's stable water level enables the establishment of beds of aquatic and emergent plants. Coves contain _Ceratophyllium demersum_, _Naja marina_, _Potamogeton pectinatus_ and _Chara_ spp. (Minckley 1979) with

Najas marina being the dominant plant (USDI - Bur. Reclam. 1972). Lake Havasu has extensive cattail marshes at the mouth of the Bill Williams River, with small cattail stands in coves and along sheltered banks.

The dominant invertebrates are chironomids, oligochaetes and Corbicula spp. Minckley (1979) noted an inverse relationship of chironomid to oligochaete numbers, with oligochaetes increasing downstream. Ostracods, crayfish, freshwater shrimp (Paleomonetes paludosus), odonates, and simuliid larvae have also been reported from the reservoir.

Lake Havasu supports a warmwater fishery with striped bass, largemouth bass, channel catfish and black crappie as the major sport fish. Green sunfish, bluegill, mosquito fish, and carp are abundant in the lake, with sunfish and mosquito fish being especially abundant in vegetated areas. Threadfin shad are abundant in the open waters of the reservoir and provide most of the forage base for the sport fishery.

Backwaters and Marshes

Backwater areas are just as important to the riverine biota today as they were historically. Supporting a more diverse fauna and flora than the channel (Minckley 1979), they provide feeding, resting and breeding areas for fish of the river.

The existing backwater or marsh areas of the lower Colorado River have several origins. Some are natural backwaters formed by the river.

Others, for example A-7 and A-10 in the Palo Verde Division, were created by dredging. Dredging has also been used to extend the life of some natural backwaters. Construction of dams and reservoirs that changed the sediment regime of the river resulted in the formation of marsh areas where sediment was deposited. Topock Marsh and Blankanship Bend are examples of this.

Regardless of origin, all backwater and marsh share certain physical characteristics. Areas with connection to the river have better water quality than isolated systems.

Culverts and other breaks in levees enable water to flow in and out of some backwaters. While the controlled water level fluctuations may drain shallow backwaters, they benefit deeper ones by providing water circulation that maintains good water quality and insures higher productivity.

Backwaters contain a variety of aquatic plants and algae. Various species of benthic diatoms, blue-green, green and brown algae, and *Chara* spp. are found in these areas. Aquatic plants, such as *Potamogeton pectinatus*, *Zannichellia palustris*; *Ceratophyllum demersum*, *Myriophyllum exalbesans spicatum*, *Najas marina*, *N. guadalupensis*, *Utrichularia* and *Lemna spp*. are found in varying abundances in the backwaters. Cattails, sedges, as well as giant reed form extensive beds around the edges and in shallow water areas.

The most abundant invertebrates are chironomids, oligochaetes, and Asiatic clams. Zooplankton populations may be quite high in the summer.

As previously stated, invertebrate populations of backwaters are more diverse than those of the main channel. Physid snails, shrimp (Paleomonetes paludosus), crayfish, odonates, coleopterans, hemipterans and dipteran species are found in and around the plant beds (Dill 1944; Marshell 1971; Minckley 1979; Ponder 1975; Singer 1973; Weaver 1971).

In backwaters with good water quality, fish are often abundant, either as residents or transients. Backwaters are especially important as nursery areas for young game fish, especially centrarchids. Plant beds provide food and cover for these young fish born in the shallow nesting areas (Singer 1973, Weaver 1971). Adult game fish utilize backwaters extensively, and fishing success is usually higher in these areas than in the main channel.

Minckley (1979) listed fish species found in the lower Colorado River and the habitats they were found in. Aside from a very few species like striped bass and smallmouth bass, backwaters were commonly utilized by all fish species present (Table 5).

Despite losses due to control of the Colorado's vagaries, backwaters still provide important habitat for plants and animals and a source of nutrients for the mainstem. Maintenance of backwaters and marshes is necessary to insure the continued viability of the river.

Table 5. Fish species found in backwaters of the lower Colorado River

Xyrauchen texanus	razorback sucker
Mugil cephalus	striped mullet
Dorosoma petenense	threadfin shad
Cyprinus carpio	carp
Motropis lutrensis	red shiner
Pylodictis olivaris	flathead catfish
Octalurus punctatus	channel catfish
Ictalurus natales	yellow bullhead
Gambusia affinis	mosquito fish
Poecilia latipinna	sailfin molly
Poecilia mexicana	Mexican molly
Micropterus salmoides	largemouth bass
Chaenobryttus gulosus	warmouth
Chaenobryttus cyanellus	green sunfish
Lepomis microlophus	redear sunfish
Lepomis macrochirus	bluegill sunfish
Pomoxis nigromaculatus	black crappie
Tilapia mossambica	Mozambique mouthbrooder
Tilapia zillii	Zill's tilapia

from Minckley 1979

Tributary Streams

While the mainstem Colorado and its major tributaries in Arizona have undergone drastic changes in the last 80 years, the tributary streams of the Grand Canyon have not been greatly changed. Recent studies funded by the National Park Service and the Water and Power Resources Service have dealt with the physical, chemical and biological parameters of these tributaries.

Most of the tributaries in the Canyon are spring fed. Depending on the geologic strata the springs originate from, water chemistry of the stream will vary (Carothers and Minckley 1980). Temperature regimes of these streams will also vary with the amount of exposure they receive. Runoff will change the water quality in terms of sediment, TDS, and nutrient load. The mainstem's salinity varies slightly through the Canyon, depending on the salinity and discharge of its tributaries. The greatest effects would be felt at the mouths of the streams (Carothers and Minckley 1980).

Tributaries commonly contain a greater abundance and diversity of aquatic macrophytes than the mainstem. Numbers of species range from 43 in the Paria River to 2 in National Canyon. These figures represent submerged, emergent and semi-aquatic plants. *Potamogeton crispus*, *P. pectinatus* and *Zannichellia palustris* are the aquatic submergents present with *Chara* spp. and *Cladophora* spp. abundant (Carothers and Minckley 1980).

The dominant invertebrates in the tributaries are oligochaetes, baetid ephemeropterans, hydropsychids, trichopterans, chironomids and simuliids (Cole and Kubly 1975).

Tributaries that carry a heavy sediment load (Paria River, Little Colorado River and Kanab Creek) have an unstable substrate and are impoverished in terms of invertebrate diversity and abundance (Carothers and Minckley 1980). In general, invertebrate productivity of the tributaries varies seasonally and from tributary to tributary. On the whole, the tributary productivity is not high compared to eastern systems, but is higher than productivity of the mainstem (Carothers and Minckley 1980).

High gradient streams support trout (rainbow, brown and brook) and abundant populations of speckled dace. Low gradient streams, such as Kanab Creek and the Paria and Little Colorado Rivers, support populations of flannelmouth suckers, bluehead mountain suckers and carp. The endangered humpback chub occurs at the mouth of the Little Colorado River.

Riverine Habitats

The remaining riverine stretches of the Colorado River represent a wide range of physical conditions from cold tailraces to warm, shallow meanders.

Tailrace Systems

The river below Glen Canyon, Hoover and Davis Dam is cold and clear. Temperatures range from 9°C. below Glen Canyon, 12-13°C below Hoover and

9-21°C. below Davis Dam (Carothers and Minckley 1980; Paulson 1980A; Jonez and Sumner 1954). Due to degradative action of sediment free water, substrates in the tailraces are composed of boulders, gravel and some sand. Tailraces are also subject to severe water level fluctuations on daily, weekly and seasonal basis, due to hydropower and water use demands. While the greatest effects occur and best cold water habitat exist in the area of the dam, effects of the dam are felt far down the river. Glen Canyon Dam impacts the river throughout the length of the Grand Canyon. Water temperatures reaching Lake Mead range from 9°C. in the winter to 21.5°C in the summer (Paulson, Baker and Deacon 1980). The cold water from Hoover extends at least to Eldorado Canyon, 32 km below the dam. The cold water flows under the warm surface water of Lake Mohave, creating a biologically productive interface. The cold water layer can be discerned throughout the length of Lake Mohave, providing a deep water trout fishery even at Davis Dam. The influence of Davis Dam's tailrace extends only a few miles down stream. The river is shallow and exposed to high insolation which rapidly warms the water.

The coarse substrates in the tailrace areas support abundant growths of *Cladophora* spp. Rooted aquatics are rare below Glen Canyon, consisting of *Elodea* spp. (McCall 1980B) and *Zannichellia palustris* (Carothers and Minckley 1980). *Chara* spp., *Potamogeton pectinatus* and *Zannichellia palustris* are found below Hoover (Moffett 1942; Jonez and Sumner 1954, Paulson 1980) with *Potamogeton pectinatus*, *Myriophyllum exalbescens spicatum*, *Certophyllum demersum* and *Najas marina* below Davis Dam (Minckley 1979).

Invertebrate populations below Glen Canyon Dam are dominated by Gammarus spp. and oligochaetes (Carothers and Minckley 1980) with chironomids, snails and leeches also abundant (McCall 1980B). As discussed previously, the construction of Lake Mohave altered the invertebrate populations below Hoover Dam. Chironomids and oligochaetes dominate the invertebrate populations with zooplankton, snails and Gammarus spp. also important (Paulson, Baker and Deacon 1980). Although chironomids and oligochaetes dominate the invertebrate fauna below Davis Dam, filter-feeding simuliid and hydropsychid larvae, and Corbicula spp. are very abundant in the reach just below the dam. Ephemeropterans, odonates, coleopterans, tipulids and Lymnaea snails are also present (Jonez and Sumner 1954; Minckley 1979).

As would be expected, rainbow trout are the most important game fish in the tailraces. Striped bass are seasonally important below Davis Dam. Carp are the most abundant fish and channel catfish and centrarchids are also found. Razorback suckers live in the hot spring areas below Hoover Dam, and also utilize the cold water areas. Flannelmouth and bluehead mountain suckers occur below Glen Canyon Dam.

Modified River Habitat

Prior to the construction of Glen Canyon Dam, the Colorado River through the Grand Canyon was largely unmodified. Currently, its temperature, discharge and sediment load are controlled by the upstream dam.

The flora and invertebrate fauna remain depauperate. Cladophora spp. is the only abundant mainstream plant. Chironomids and oligochaetes dominate the fauna, with Gammarus spp., physid, snails, and simuliids also present throughout the system (Carothers and Minckley 1980). The shifting sand substrate, high current velocity, sediment load and depths that characterize much of the river contribute to the sparse invertebrate population (Carothers and Minckley 1980). The clearer water and coarse substrate between Lee Ferry and the Little Colorado River supports higher invertebrate productivity and diversity.

Fish species found in the Grand Canyon include both warm and cold water species. Rainbow trout, brown trout, brook trout, carp, fathead minnows, channel catfish, largemouth bass, sunfish, and striped bass comprise the non-native fish population, with humpback chubs present in some areas, especially near the mouth of the Little Colorado River. Flannelmouth and bluehead mountain suckers are found throughout the mainstem.

The flowing water reaches below the tailrace of Davis Dam have been extensively modified by dredging, bank improvements, and other river management devices. This region is divided into 10 management divisions by the Water and Power Resources Service (fig. 11 and Table 6). Minckley (1979) studied the river habitats in these divisions.

Table 6. River-mile designations, lengths, and estimated percentages of bank modifications through rip-rap, or other armoring techniques, or inundation, for 10 operational divisions on the lower Colorado River, 1973.

Divisions	River Miles (old system)	Length in km	Percentage Modified
Mohave Valley (MO)	422.0-464.0	67.6	65.4
Topock Gorge (TO)	464.0-478.0	22.5	0.0
Havasu (HA)	478.0-524.5	74.8	100.0
Parker (PA) 1/	524.5-568.8	71.3	23.0
Parker-I	----	----	50.0+
Parker-II	----	----	4.0
Palo Verde (PV)	568.8-596.6	44.7	58.0
Cibola (CI)	596.6-619.9	37.5	86.0
Imperial (IM)	619.9-657.2	60.0	35.0
Laguna (LA)	657.2-662.6	8.7	100.0
Yuma (YU)	662.6-683.7	33.9	90.0
Limitrophe (LI)	683.7-704.2	33.0	6.0

1/ Parker Division is divided into a modified reach (Parker-I) and a relatively unmodified reach (Parker-II).

from Minckley 1979

In areas below dams or channels with gravel or boulder substrates, Cladophora spp. and other attached algae are very abundant. Rooted aquatics are also abundant below Davis and Parker Dams and in the Parker Division, sparse in the Imperial and Limitrophe Divisions, and virtually absent elsewhere. Plants established ephemeral beds on temporarily stabilized sand or gravel bars throughout the river.

Potamogeton pectinatus is the most common species in the channel, found in water to 4.5 m and in current to over 1.0 m/sec. Myriophyllum spicatum exalbescens, Myriophyllum brasiliense and Chara spp. were in shallower (to 2.5 m), slower (less than .5 m/sec) water with Ceratophyllum demersum, Potamogeton foliosus macellus, Zannichella palustris, and Najas guadalupensis in even shallower, slower water in areas with minimal daily water fluctuations (Imperial and Limitrophe Divisions). Najas marina, the most common plant in backwaters, was seldom found in the channel except near the entrances to backwaters in quiet water. Cattail, sedges and giant reed line banks along the river.

The distribution of aquatic invertebrates is related to substrate type and amount of particulate organic matter in the water. Filter feeding simuliid dipterans, hydropsychid trichopterans and Asiatic clams are abundant below Davis and Parker Dams, utilizing the particulate material in the tailrace. In coarse substrate areas with flowing water, tabanid dipterans, hydrophylid beetles, and baetid ephemeropterans are found along with simuliids and snails. Odonates are locally abundant, as are other invertebrates such as freshwater shrimp, crayfish and a variety of insect groups. The dominant invertebrates are the chironomids, oligochaetes, and Asiatic clams. The benthic fauna is best developed below dams, in areas with aquatic plants and coarse substrates, and quiet eddies. Shifting sand bottoms, typical of the lower divisions, have only a sparse fauna.

Similar distribution patterns exist for fish species. In the regions below dams, unchannelized reaches and areas with aquatic plants the fish fauna of the channel is both more abundant and more diverse than that in the sand bottomed, modified reaches. Red shiners forms the bulk of the fish population in sandy reaches, with mosquitofish, threadfin shad and a few centrarchids making up the remainder of the population. Backwaters off the channel have higher diversities of fish species.

Species found in other river areas (below dams, and in quieter water) include rainbow trout, channel and flathead catfish, threadfin shad, red shiners, carp and centrarchids.

III. Life Histories of Important Native and Sport Fish

THREADFIN SHAD

I. Introduction

Threadfin shad, Dorosoma petenense, were introduced to the lower Colorado River under a tri-state agreement in 1953. Widely distributed in Lakes Mead, Mohave and Havasu in 1954 and 1955, it was distributed from Mead to Mexico by 1956 (LaRivers 1962). Threadfin were chosen to provide forage for game fish in the river. They never grow out of forage size, are extremely prolific, are not dependent on the littoral zone, and utilize open water plankton thus not directly competing with game fish (Roden 1978).

II. Life History

Reproduction

Fecundity

Threadfin shad's ability to quickly expand into a new habitat is due to the high reproductive potential of the species. Eggs per female range from 800 (Minckley 1973) to over 12,000 in a 10.2 cm female (Burns 1966). Females average 2,300 eggs per gram of ovary (Minckley 1973). Threadfin may spawn at less than 1 year old (Miller 1963).

Spawning behavior

Threadfin begin to move inshore to spawn in mid-April (Nevada Dept. Game and Fish 1962). Gonad development begins in late March and peaks in April-June. A second smaller peak may form in November (Deacon, et al, 1972). Spawning by older fish (age III) peaks in June while age I fish did not peak until July. Younger fish did not show a second spawning peak (Deacon, et al, 1972). Threadfin hatched in the spring may spawn in the fall.

Spawning activity begins in the early morning, 2-3 hours after sunrise, while waters are still calm and the wind is low (Minckley 1973). Schools of shad move along the shore in shallow water. Ripe females leave the school, accompanied by 2-20 males, in search of appropriate substrate. Shad lay their eggs on vegetation or debris. Once near an appropriate spot, the males harass the female and violent, egg explusion sideways movements occur. Eggs are fertilized as they are released. Violent splashing continues up to 5 seconds. After the spawning act, the female may rejoin the school or search out another spawning site. Suitable spawning sites are 5-25 cm deep, rarely are deeper areas used (Minckley 1973). Gravel bars provide good spawning habitat (Gumtow 1965). There may also be limited pelagic spawning (Nevada Dept. Fish and Game 1971, 1972). Few shad survive to spawn more than once. Heavy mortality due to physiological stress occurs after spawning (Minckley 1973).

Egg and Juvenile

Threadfin eggs are adhesive and sink to the bottom and adhere to brush or to a point where their density equals that of water (Roden 1978). Hatching occurs in 3 days at 26.7°C (Kimsey 1958). The threadlike, planktonic young are 3.8 mm long. York sac absorbtion is completed in 3 days and metamorphosis occurs at 1.3 cm (Burns 1966). By the second week of June, the young are about 2.5 cm (Nevada Dept. Game and Fish 1962).

Age and Growth

Age I threadfin reach 10.2 cm by July following hatching (Auburn Univ. 1960). Maximum size rarely exceeds 10 cm, but individuals over 17.8 cm have been found (Kimsey, et al, 1957; Minckley 1973). Reports of 20-25 cm (Eddy 1969) and 33.0 cm (Swingle 1965) exist. Growth rates of the sexes are fairly consistent, however, the largest fish in a population are likely to be females. There may be a differential mortality to account for this (Minckley 1973). Threadfin are short-lived with some individuals reaching age II (Miller 1963).

In Lake Mead there are three known age classes. Age I fish reach 3.5-5.0 cm TL, Age II fish are 8.0 cm TL and Age III fish average 13.5-15.0 cm TL. There may be a few fish older than Age III but there is no documentation (Deacon, et al, 1972).

Feeding

All threadfin are capable of utilizing a wide variety of food items. The primary foods are zooplankton, algae, organic debris and small insects (LaRivers 1962, Deacon, et al, 1962, Roden 1978). Shad select prey items (Burns 1966), especially larger zooplankton which may have more nutritional value (Deacon, et al, 1972).

Threadfin have a gizzard-like foregut that masticates the food items. Sand is found in threadfin stomachs and may be actively sought and ingested to aid in grinding and digesting food materials (Kimsey, et al, 1957); Minckley 1973).

Movement

Threadfin shad school in open water throughout life. They are limnetic during daylight, remaining in deep water. On dark nights, schools disperse near the water surface over shallow and deep areas. On bright, moonlit nights, schools do not disperse (Minckley 1973). During the summer, shad are usually within the top 15 m of water (Burns 1966) but from October to April they descent to deeper waters. In Boulder Basin in Lake Mead, schools of shad have been found at 47 m in winter. These shad still surface and disperse at night (Roden 1978).

Threadfin are attracted to areas of current and may form large concentrations below dams and inlets. They will orient facing the flow. In circular eddies they will swim in a circle facing the flow (Burns 1966). In Lake Mohave, shad concentrate at the underflow point, where the cold river water sinks under the warmer lake water. This habitat provides an excellent food base (Roden 1978).

Physical factors

Threadfin shad are euryhaline. They live in fresh, brackish or ocean waters within its current range (Burns 1966). In Texas, salinities of

10-20 ppt were preferred (Carlander 1969). They are found in turbid drains in the lower Colorado (Gumtow 1967), and clear lakes, but no definite data on responses to turbidity are available.

Lethal temperatures for shad are reported at $7^{o}C$, $1.1^{o}C$ (Carlander 1969) and $5^{o}C$ (Griffith 1978). Feeding and schooling behavior decrease at temperatures below $10^{o}C$ with death from cold shock more related to final temperature reached than the number of degrees dropped (Griffith 1978). Shad can survive the winter with a minimum temperature of $9^{o}C$ (Carlander 1969). Oxygen supersaturation is also lethal (Burns 1966).

III. Interactions

As a forage fish, threadfin shad have been very successful. Increased growth rates of game fish after shad were introduced has been reported for bluegills and other sunfish in Alabama (Auburn University 1960), for black crappies in Roosevelt Lake (Beers and McConnell 1966), trout in the Colorado River near Needles (Holquist 1961) as well as largemouth bass. Where shad are introduced, diets of the game fish large enough to eat them immediately include large percentages of shad. This has been shown in Lake Powell for trout (May, et al, 1975) and bass (May and Thompson 1974), and in Pine Flat Lake in California (Burns 1966) and Santee-Cooper Reservoir in South Carolina where shad supported the massive striped bass population (Stevens 1964).

Small shad are used extensively by game fish, thus reducing predation pressure on fry of game fish (Ringo 1961). A population dominated by large shad indicates a predator population dominated by small fish, unable to utilize large shad (Ringo 1961).

Growth rates of young centrarchids may decrease after shad are introduced. More young centrarchids survive and compete with each other, and with the abundant small shad for food (Miller 1971). The result is an abundance of stunted centrarchids (Ringo 1961). Evidence for direct food competition exists in Pena Blanca Lake, Arizona (Gerdes and McConnel 1963, McConnell and Gerdes 1964) and Millerton Lake, California (Burns 1966). There is no evidence that shad surpress the growth of young bass in Lakes Mead or Mohave (Nevada Dept. of Fish and Game 1976a, 1976b). Shad in these lakes are strongly pelagic and have not been observed in habitat critical for young bass survival.

Another problem that has been documented is the over-utilization of the shad population with the subsequent "bust" of the game fish population. This was demonstrated with the striped bass fishery in Santee-cooper Reservoir (Stevens 1964). The bass population reduced the shad population to a point where the shad could not support the numbers of stripers present, and 30-50 percent of the bass starved to death.

RAINBOW TROUT

I. Introduction

The rainbow trout, Salmo gairdneri, is an extremely popular game fish that is widely stocked in the cool water areas of the Colorado River. First stockings were made in the river below Hoover Dam in 1935 and between 1940-1951 they provided excellent fishing in the area that became Lake Mohave (Jonez and Sumner 1954). Currently, rainbow trout are stocked in Lake Mead (since 1969), Lake Mohave, below Hoover and Davis Dams, and other suitable areas by the states of Arizona, California, and Nevada and the U.S. Fish and Wildlife Service.

II. Life History

Reproduction

Maturation

Rainbow trout reach maturity between 1-6 years of age, with most fish spawning at age 3. Males may mature at 1 year, females at age 2-6. Age at maturity is a function of the particular strain involved (Greeley 1932; Mottley 1947; Minckley 1973). Size at maturity is also extremely variable, with some fresh water populations weighing less than 0.45 kg at maturity and sea-run populations maturing at 0.45-1.36 kg (McAfee 1966).

Fecundity

Fecundity is directly related to the size of the fish. Small fish may produce only 200 eggs; large fish more than 9000. Fish less than 0.45 kg contain less than 1000 eggs, 1.36-1.8 kg fish produce 2000-4000, and 4.5 kg fish may have 8000 or more eggs (Mottley 1947; Needham 1938; Nicholls 1958; Simon 1946). Size of the egg is not related to size of the female (Scott 1962). Mature eggs average 5.0 mm (Simon 1946).

Spawning behavior

Rainbow trout migrate upstream to spawn. The female trout constructs a nest, called a redd, in gravel along a fast riffle or the end of a pool. The female digs the redd by turning on her side and using rapid, vertical tail movements. The completed nest may be a few centimeters to .3 m in depth and a meter or more in diameter, depending on the size of the fish. The female will often settle into the nest during construction to test the size (McAfee 1966). After the nest is completed, a dominant male chases the other attendant males away and courts the female, occasionally rubbing her with his snout. The dominant male, female, and occasionally another male settle into the pit, vents close together. Eggs and sperm are deposited simultaneously. The spawning act takes several seconds, after which the female buries her eggs with gravel she dislodges by digging another redd upstream from the first. Spawning is repeated until the female is spent. Spawning may take 12 hours or as long as a week (Needham and Taft 1934). Spawning in trout is very efficient, with few eggs retained and fertilization exceeding 98 percent (McAfee 1966).

Trout do not defend their nests, the eggs develop unattended (Needham and Taft 1934).

Rainbow trout spawn at tempratures of 5.5-13.0^{o}C (Carlander 1969). Wild populations and most hatchery stocks spawn in the spring, with spawning runs beginning in December and lasting until March (in Lake Mohave). Hatchery developed strains of fall spawning rainbow are also present in Lake Mohave. Their runs occur in August and September (Jonez and Sumner 1954). Streams with clean, silt-free gravel and moderate current velocity provide necessary spawning habitat (McAfee 1966).

Substantial weight loss and physical trauma accompany spawning. Weight loss can be as high as 1/3 in females and 1/2 in males (Rayner 1949). Repeat spawners lose less than first timers (Mottley 1938). Distance travelled also affects weight loss (McAfee 1966). Females often sustain fin fraying and bruising from redd construction (Walden 1964).

Prior to the construction of Lake Mohave, the Colorado below Hoover Dam provided about 65 km of spawning habitat. At the present time, only 3 km of suitable areas exist and a few trout utilize the area. Most trout do not spawn and reabsorb their eggs (Jonez and Sumner 1954). A similar situation exists below Lake Powell and Davis Dam, where widely fluctuating water levels often expose suitable gravel bars.

Embryo Development

The incubation period is directly related to water temperature. At 4.4^{o}C, eggs begin to hatch in 80 days; at 10^{o}C at 31 days and 15.6^{o}C at

19 days. Actual hatching time will also vary with temperature, taking 14 days at 5.7°C and 3 days at 17.6°C. Best egg development is between 5.6-13.3°C (Embody 1934). Embryo survival in nature is positively correlated with dissolved oxygen water flow through the gravel (Coble 1961). Survival of eggs in redds is usually good, averaging 90 percent (Walden 1964).

Fry and Juvenile

Fry are about 17 mm at hatching (Wales 1941) and remain in the gravel until the yolk sac is absorbed, from several days to 2-3 weeks. At emergence they are 1.3 cm in length (Shapovalov and Taft 1954). Survival of free-swimming fry is low, with predators consuming large numbers of small trout (Walden 1964). The fry remain near the hatching site in loose schools for a few days. They become solitary and more widely distributed (McAfee 1966). At water temperatures below 13°C, the fry hug the bottom, remaining near the redd or attempt to go upstream (Carlander 1969). Water level fluctuations have no effect on this behavior.

Fry begin to feed 15 days after hatching, consuming small plankton. Larger prey, including zooplankton and aquatic insects, are consumed as fry grow. Fingerling trout have been stocked below Davis Dam to control simuliid flies. Trout stomach analysis showed that 95 percent of prey was this fly larvae (Arizona Game and Fish 1977A).

Preferred temperature for fingerlings is 13°C (Garside and Tait 1938) with an upper lethal temperature of 24°C for fish acclimated to 11°C (Black 1953). Minimum oxygen requirements are 1.50-1.54 ppm at 11-13°C (Townsend and Earnest 1940).

Adults

Age and Growth

Rainbow trout live a maximum of 7-11 years (Shapovalov and Taft 1954) but few fish survive beyond age 4 in areas of heavy fishing pressure (McAfee 1966). Age structure among populations vary considerably. Age at maturity, population density, food availability, spawning conditions, sex, water temperature and habitat type all influence the population structure (Mottley 1947; Minckley 1973; McAfee 1966; LaRivers 1962; Walden 1964).

Growth rates are generally faster in large bodies of water than in small streams. An adult from a small stream may measure 20 cm while an adult from a large lake or river may reach 13.6 kg in weight (Mottley 1947). Yearling trout reach 7.5-25.0 cm; age 2 fish 12.5-40 cm and age 3 fish 10.0-50.0 cm (McAfee 1966). Older fish may reach 70 cm or more. Rainbow trout in the Colorado River are usually stocked as 20-25 cm catchables (Roden 1978). Tag and recovery data from Lakes Mead and Mohave show good to excellent growth. In Lake Mohave, the average length of trout stocked between 1968-1974 was 23.3 cm. These fish grew an average of 2.43 cm per month per 6-month period and 1.60 cm per month per 12-month period (Roden 1978).

Feeding

Trout feed both in open water and forage on the bottom, consuming a wide variety of food items. Aquatic and terrestrial insects, zooplankton and fish are usually the most important dietary components. Oligochaetes, molluscs, amphipods and plant material are of lesser importance (Needham 1938; and others). Small trout feed more heavily on invertebrates and plant material while larger individuals are more piscivorous (Sigler and Miller 1963; Eddy 1969).

Growth rates in lakes where the primary foods are zooplankton and insect larvae are rapid up to 30.5-35.6 cm, but slow after that size. Where forage fish are available, growth remains rapid and fish reach large sizes (McAfee 1960). Rainbow trout in Lake Mead show a seasonal dietary shift. Chironomids dominate the diet in winter, with threadfin shad the second most important food item. Threadfin shad become the dominant food over chironomids and green sunfish in the spring and maintain dominance over the summer (Deacon et al 1972).

Gammarid amphipods (fresh water scuds) were an important food below Hoover Dam prior to the formation of Lake Mohave. After Davis Dam was completed, the riverine invertebrate and algae populations disappeared, and until the mid 1950's, the trout in the river were in very poor condition (Jonez and Sumner 1954). Presently, threadfin shad and chironomids are the most important foods in Mohave. Shad are most important in the warm water areas, while chironomids are dominant in the cold areas. The greatest shad utilization occurs from April-December (Roden 1978). Trout below Glen Canyon dam utilized snails and bloodworms as well as algae. Only trace amounts of phytoplankton or zooplankton are consumed (Stone 1964).

The introduction of threadfin shad has had a profound effect upon trout diets in the lower Colorado. Prior to shad introductions, the primary food of trout was algae and zooplankton (Jonez and Sumner 1954). When shad were introduced into Lake Powell, they cam to dominate the diet of all sizes of trout. Fish under 300 mm switched from a zooplankton to a small shad diet. Fish over 300 mm had also consumed primarily zooplankton prior to shad introduction. There was also a marked increase n growth after shad were introduced (May, Hepworth, Starostka and Gloss 1975).

Movement

Rainbow trout in large lakes are limnetic. During the warm portion of the year, they are found in deep water where the temperature is more suitable for them. Depths of 30-45 m may be reached or exceeded (McAfee 1966; Nevada Dept. Fish and Game 1975B).

Unlike most freshwater fish, rainbow trout are migrants. In addition to spawning runs, trout in lakes or large rivers travel freely. Tagging studies in Lake Mohave on trout planted at Willow Beach showed 39 percent remained in the immediate vicinity, 41.2 percent moved upstream an average of 4.4 miles and 19.8 percent moved downstream an average of 10.4 miles. Some moved as far as Davis Dam (Jonez and Sumner 1954). Trout planted near El Dorado Landing showed more erratic movements, with 26.6 percent moving upstream an average of 11.2 miles with 40 percent moving downstream 20.8 miles. Seasonal movements in Lake Mohave are associated with temperature stratification of the basin, reproductive maturity and concentration of food organisms (Roden 1978). Rainbow also possess a downstream obsession to seek a lake or large reach of river (Walden 1964; Eddy 1969). This obsession may be responsible for the spread of rainbow trout into Lake Mead from the Grand Canyon and the Virgin River (Jonez and Sumner 1954).

Physical factors

Rainbow trout prefer well oxygenated, cool water. They can tolerate temperatures from $0^{o}C$ to over $26^{o}C$ (McAfee 1966) but prefer temperatures below $21^{o}C$. Waters low in calcium and magnesium have lethal limits of $25^{o}C$ (Angelovic, Sigler and Neuhold 1961). Lethal temperatures vary from $21\text{-}26^{o}C$ (Roden 1978). High temperatures also increase sensitivity and mortality to fluoride concentrations (Carlander 1969). Final preferred temperature is not greatly influenced by acclimation temperature (McCauley, Elliot and Read 1977).

Lethal oxygen levels are closely related to temperature. At $11^{o}C$, 1.05 ppm oxygen is lethal, while at $20^{o}C$, 1.51 ppm is lethal. Trout in Lake Mead were taken at 33-41 m in water $13.9\text{-}14.4^{o}c$ with 5.9 ppm oxygen (Nevada Dept. Fish and Game 1970). Oxygen supersaturation does not cause ill effects (Overholtz, Fast, Tubb and Miller 1977).

Trout tolerate pH's of 5.8-9.5 and alkalinities of up to 4700 ppm are tolerated by some strains (McAfee 1966). Steelhead trout spend part of their lives in seawater. Even strictly freshwater trout can acclimate to 0-3.5 percent salt (Black 1951).

III. Interactions

Rainbow trout, especially the hatchery reared strains, are not efficient predators or a good competitor when other species are present (Roden 1978). Although rainbow will prey on threadfin shad, green sunfish (Jonez and Sumner 1954), tui chubs and pond smelt (*Hypomesus olidus*) (McAfee 1966), they do not have major impacts on forage populations.

Many species of fish will prey on rainbow trout. Large trout will prey on young trout and unwary hatchery fish. Tui chubs, black bass, brown and lake trout and striped bass all prey on rainbows.

The introduction of striped bass into the lower Colorado put predation pressure on rainbow trout in Lake Mead (Nevada Department of Fish and Game 1980B) and below Davis Dam (Arizona Game and Fish Dept. 1970). Below Davis Dam, within 13 days of a trout plant, of 24 stripers caught, 20 of them had collectively eaten 24 trout.

IV. Fishery

Rainbow trout were first stocked below Hoover Dam in 1935 and provided good fishing down to Searchlight (Jonez and Sumner 1954). After the formation of Lake Mohave, trout fishing declined in the Black Canyon area below Hoover Dam, however, as the system stabilized and stocking continued, fishing became good again. Trout are a major component of the catch in Lake Mohave, even at Katherine Landing at the warm water end of the lake. In the years 1975-79, rainbow have made up 48-68 percent of the catch (Nevada Department of Fish and Game 1980A) and have the highest angler effort.

Trout have been stocked in Lake Mead since 1969, but were present in limited numbers prior to that year. Although only 3.1 percent of the fishing effort is directed to salmonids, they make up 1.0 percent (1970) to 19.1 percent (1975) of the catch (Nevada Department of Fish and Game 1980B). Trout fishing in Mead has declined drastically since 1975, possibly due to striped bass predation and migration out of the lake (Roden 1978).

Trout are also stocked below Davis Dam where they provide good fishing. Winter plants of trout have been made in various locations along the lower river, including the Colorado River Indian Reservation (Gumtow 1967).

CHANNEL CATFISH

I. Introduction

The channel catfish, *Ictalurus punctatus* (Rafinesque) is a highly adaptable warmwater fish native to the Missouri and Mississippi River drainages. Introduced into the Colorado River in 1892-1893, they soon spread throughout the lower river. At the present time catfish are found in all areas of the river and provide a substantial sport fishery.

II. Life History

Reproduction

Maturity

Maturity of channel catfish varies greatly depending on geographic location and condition of the fish (Roden 1978). In Louisiana, most were mature at 26.7 cm (males) and 30.5 cm (females) (Davis and Posey 1938). Females in Iowa matured at 33-46 cm while males matured at slightly smaller sizes (Harlan and Speaker 1956). Smallest maturities in the Mississippi River were 29.2 cm for males and 31.8 cm for females (Greenbank and Monson 1947) with most fish mature between 30.5-38.1 cm (Barnickol and Starrett 1951). Males mature at smaller sizes than females, and within any population there is wide variation in maturation lengths within each sex. One female was mature at 17.8 cm while another was immature at 39.4 cm. A 21.6 cm male was mature whereas a 43.2 cm male was not (Davis and Posey 1958). For most populations, age at maturity is 4-6 years (Carlander 1969).

In the Colorado River, the smallest mature females seen were 17.8 cm (Dill 1944) with fish 17.8-37.5 cm possibly having spawned that year. The largest immature female seen was 26 cm. Lake Mead catfish reach maturity by 33 cm and 3 years old (Jonez and Sumner 1954).

Fecundity

Fecundity will vary with the age and size of the female. A 25.4 cm fish produced 2000 eggs (Canfield 1947) and a 66 cm fish produced 34,500 eggs (Dill 1944). Weight of the fish will also influence egg production. Fish 1-4 pounds (.45-1.8 kg) produce 4,000 eggs per pound of body weight, while larger fish produce 3,000 eggs per pound (Clemens and Sneed 1957). The range is 2,000-70,000 eggs (Carlander 1969). Catfish in Lake Mead had egg counts ranging from 3,000 in a 30.5 cm fish to 5,500 in a 38.1 fish (Jonez and Sumner 1954). Immature eggs are 2.5 mm in diameter (Dill 1944). Mature eggs are 3.53 mm (Shira 1917) in diameter with a range of 3.5-4.0 mm (Menzel 1945). They average 450-500 to the ounce and are yellow when deposited, turning yellowish-brown near hatching (Brown 1942).

Spawning behavior

Catfish will often ascend tributaries of large lakes or rivers seeking good spawning sites. Catfish prefer secluded, semi-darkened places such as hollow logs, submerged muskrat runs, undercut banks, under rocks and holes (Sigler and Miller 1963; Harlan and Speaker 1956; and others). In

Lakes Mead and Mohave most spawning efforts occur in the main body of the lake, along protected rocky areas (Roden 1978). In the lower river typical spawning habitat is utilized where it is available.

The male channel catfish chooses and cleans the nest site (Brown 1942; Davis 1959). After cleaning, the male secretes a mucus on the nest which provides a smooth, waxy appearing surface (Brown 1942). Female catfish spawn only once a year. Males may spawn several times (Clemens and Sneed 1957). After spawning, the male hovers over and guards the nest. He fans the eggs with his pelvic fins to clean and aerate them (Clemens and Sneed 1957). The mass of eggs is pressed and packed gently to aid aeration and movement of the embryos. If the eggs are disturbed at any time, the male, or female, may devour them (Sigler and Miller 1963).

The male catfish is a very aggressive guardian (Minckley 1973). He continues to guard the nest until the fry hatch, then will accompany the school of fry for a few days before leaving them on their own (Sigler and Miller 1963).

Reproductive activity begins in the late spring at temperatures of 21°C. Spawning extends from April to August with a peak in June and July. Some populations may spawn as early as March or as late as September (Carlander 1969). In the lower Colorado catfish spawn in June-August (Arizona Game and Fish Department 1961). Ideal spawning temperature is 26.7°C. with an upper limit of 29.4°C. (Clemens and Sneed 1957). Optimal dissolved oxygen concentrations are similar to those recorded for adults.

Maximum salinity for successful spawning is 2 ppt. (Perry 1973). Spawning will take place in water as shallow as 2 meters but actual depths are not known. Usual depths are deep enough that lake level fluctuations do not hamper reproductive success (Jonez and Sumner 1954). Catfish will not spawn in clear ponds unless some sort of cover is provided (Scott and Crossman 1973).

Embryo development

Catfish eggs will not develop at water temperatures below 15.5°C. Optimal temperature is 27°C. (Brown 1942; Clemens and Sneed 1957). Upper lethal temperature is 29°C. (Brown 1942). Oxygen levels of 7 ppm or higher (similar to those preferred by juveniles) are preferred. Salinities up to 16 ppt are tolerated but levels below 10 ppt have the best survival (Allen 1970).

Eggs hatch in 9-10 days at 15.5-18.3°C.; 5-7 days at 25°C. (Brown 1942) and 6 days at 27.8°C. (Clemens and Sneed 1957).

Fry and Juvenile

Fry remained on the bottom of aquaria for 2 days after hatching, then they swam up and began to feed (Clemens and Sneed 1957). The larvae remain near the nest for several days (Miller 1966). As the fish reach 15-20 mm TL, they move into shallow nursery areas. These areas may consist of rocky riffles and debris covered sand and gravel bars (Cross

1967, Miller 1966). Fry consume plankton and benthos. Cover is necessary and may consist of weed beds or turbid water that effectively hides the fish. Marzolf (1957 in LaRivers 1962) found that fry survival in ponds was greatest when secchi disk readings were less than 50 cm. He also states that extremely dense weed beds are not optimal for young fish because of the high numbers of predatory insects found in them.

Juveniles up to 16.5 cm are common on shallow shorelines along flowing water over sand and mud substrates (Bryan, et al, 1976). They form loose schools that may last until fall.

Until 10 cm in length, catfish feed primarily on aquatic insects or bottom arthropods (Bailey and Harrison 1948; Darnell 1958, and others) but become omnivorous or piscivorous thereafter (Dill 1944; Russell 1964; Stevens 1959).

Maturing juveniles leave the shallows for deeper water (Scott and Crossman 1973). Juveniles reach 2-2.5 cm by mid summer (Jonez and Sumner 1954). Juvenile growth rates and food conversion efficiency are optimal between 28-30^{o} C. (Andrews and Stickney 1972; Andrews, et al, 1972). Upper lethal temperature is the same as for larvae (37.8^{o} C.) (Allen and Strawn 1968). Dissolved oxygens of 7 ppm are optimum (Andrews, et al, 1973) with 5 ppm and above preferred at 25-28^{o}C. Levels below 0.7 ppm are lethal (Moss and Scott 1961).

Young catfish are found in riffle areas and areas of turbulence near sand bars (Davis 1959) and tolerate faster water than adults, often feeding in riffle areas (Trautman 1957). Little is known of their habitat in lakes.

Adults

Age and Growth

Growth rates in channel catfish vary greatly. Older reservoirs have slower growth than new reservoirs (Miller 1966) and growth is faster in areas with no natural reproduction (Regier 1963). Reported lengths at 1, 3, and 6 years of age range from 4.6-13.7 cm, 15.5-41.4 cm, and 26.4-55.6 cm respectively (Miller 1966). In Lake Mead, fish average 11.4-17.8 cm at age 1 and 20.3-30.5 cm at age 2 (Jonez and Sumner 1954).

Channel catfish average 114 gm at 25.4 cm, 454 gm at 38.1 cm and 1.8 kg at 56 cm (Miller 1966).

In many areas, catfish do not live beyond age 7 (Davis 1959; Finnell and Jenkins 1954) but in some populations, fish may reach 8-12 years of age (Santee Cooper Reservoir, South Carolina and Utah Lake, Utah) (Miller 1966).

Feeding

Channel catfish are omnivorous. They feed heavily both at night and during the day, usually from the bottom but some food is taken from the surface (Bailey and Harrison 1948). Adult diets include fish, amphibians, insects, crustaceans, mollusks, insects and plant material (Roden 1978). In Lake Mead, catfish consume fish, insects and plankton with the most important foods being fish and algae (Deacon, et al, 1972). Fishes eaten included young bass, crappie, sunfish and catfish (Jonez and Sumner 1954). Plant material forms an important dietary component. Fish from the Imperial Valley were eating Najas sp. and fragments of bulrush (Dill 1944). Sago pondweed, Potamogeton pectinatus was the principle food of 20-60 cm catfish in Lake Havasu (Kimsey, et al, 1957) with crayfish and centrarchids of lesser importance. These same foods were consumed in the Parker Dam-Headgate Rock segment of the river. Filamentous algae was the dominant food of 28 cm fish at Palo Verde Weir.

Movement

Catfish are most active at sunrise and sunset (Stevens and Tiemeier 1961) although they move extensively in feeding at night. They spend the day in deeper water under logs or deep holes (Davis 1959) and move into the shallows to forage (Sigler and Miller 1963).

Catfish are usually found on or near the bottom but during the summer in Lake Mead, catfish were observed at the water surface and in rocky coves (Jones and Sumner 1954). During the spawning season and warm water periods, catfish move extensively; once the water cools, activity levels fall (Roden 1978).

Fish may tend to move downstream in the fall (McCammon 1956) and spend the winter in deeper water (Arizona Game and Fish Department 1972). Channel catfish inhabit moderate to swiftly flowing streams and rivers but are very cosmopolitan in their present distribution. They are found in sluggish streams, lakes, reservoirs and farm ponds (Miller 1966). They prefer sand, gravel or rubble bottoms with or without mud mixed in. Where mud is present in the substrate, water is usually flowing (Bailey and Harrison 1948). Catfish seldom live in dense aquatic vegetation (Trautman 1957). In the Colorado River, many adults inhabit deep quiet areas downstream from sandbars (McCammon 1956).

Physical factors

Although catfish are known to prefer clean water, they often live quite well in muddy rivers. Dill (1944) reported catfish from the silty Grand Canyon and the "chocolate brown" New and Alamo Rivers. Growth rates are less in turbid waters than in clear waters (Miller 1966) but lethal turbidities, determined to be 85,000 ppm (Wallen 1951), are rarely reached under natural conditions.

Catfish do not grow well at temperatures under 21°C (Macklin and Soule 1964); McCammon and LaFaunce 1961). Optimum temperatures for growth are 26-29°C (Shrable, et al, 1969). Upper lethal temperatures range from 30.3-33.5°C for fish acclimated at 15-25°C. Lower lethal temperatures were 0-6°C for the same acclimation temperatures (Carlander 1969). The highest recorded temperature for channel catfish survival was 35°C (Moss and Scott 1961). Feeding ceases at 12°C (Randolph and Clemens 1976).

Optimal dissolved oxygen is 7 ppm (Andrews, et al, 1973). Lethal oxygen levels increase with increasing temperature. At temperatures of 20, 30, and 35°C shock minimum oxygens are 0.95, 1.03, and 1.05-1.09 ppm and acclimation minimums are 0.70-0.97, 0.85-0.96, and 0.83-1.12 ppm (Moss and Scott 1961). Growth is retarded at oxygen concentrations below 3 ppm but active distress does not occur until 1 ppm or below (Simco and Cross 1966). Catfish do not feed at oxygen concentrations below 3-5 ppm (Randolph and Clemens 1976).

In clear to moderately turbid streams, current flows of 15-150 cm/sec are acceptable provided fixed cover is available (Miller 1966, Cross 1967). In more turbid streams, slower, less than 15 cm/sec flows are preferred and there is less dependence on fixed cover (Bryan, et al, 1975). Catfish do not do well in static or eutrophic systems, or in systems receiving heavy agricultural runoff (Bryan, et al, 1976).

III. Interactions

Because of its omnivorous food habits, the channel catfish is a direct competitor with most centrarchids. Aquatic insects, crayfish and other food resources are sought by all species. The young fish also share similar nursery habitats. Catfish reduced the condition and growth of redear and bluegill sunfish, probably by competing for chironomids. The resulting decrease in bluegill reproduction also limited bass growth (Brown 1965).

Channel catfish do not spawn in the same areas as other fish, and spawn later in the year. Because water fluctuations do not affect catfish reproduction, they may be more numerous in nurseries than centrarchid fry and be able to out compete them for limited food resources. However, predation on young catfish by bass and bluegill is quite heavy, and in clear ponds with little cover, survival may be very low (Miller 1966).

Catfish also consume young centrarchids and will utilize threadfin shad, competing directly with adult centrarchids.

Flathead catfish in the lower Colorado River also prey on channel catfish. While this causes an impact to the channel catfish population, there are also negative impacts to the flatheads. Many flatheads are found dead with a channel catfish, spines extended, stuck in its throat. (Arizona Game and Fish 1972).

IV. Fishery

Prior to the construction of Davis Dam, the channel catfish were the second most numerous game fish in the stretch of river that became Lake Mohave (Priscu 1978). Within Lakes Mead and Mohave, catfish are a popular sport fish. In Mead, catfish have made up 14-32 percent of the catch in 1973-1979 (Nevada Department of Fish and Game 1980B). They are less sought after in Mohave, making up 3-4 percent of the yearly catch (Nevada Department of Fish and Game 1980A).

In the lower river, especially the mainstem, catfish provide a significant fishery. From Topock to the Limitrope Division, channel catfish provide between 10-50 percent of the sport catch. The best areas are in the areas of Parker, Ehrenburg and Imperial Reservoir, with Topock, Yuma and Mittry Lake being less productive. A few catfish are taken in the cold water areas below Davis, Hoover, and Glen Canyon Dams (Arizona Game and Fish Department creel census data).

STRIPED BASS

I. Introduction

The striped bass, *Morone saxatilis* (Walbaum), is a marine or estuarine fish native to the Atlantic coast of North America. "Stripers" were introduced to California's Pacific coast in the Sacramento River in 1879 and now range from San Diego, California to the Columbia River in Oregon (Edwards 1974).

After the successful establishment of striped bass into Santee-Cooper Reservoir, South Carolina, in 1954 (Scruggs and Fuller 1954), the species was considered for introduction into the Colorado River. Stripers were first planted in 1959 (St. Amant 1959) by California and again in 1962 by California and Arizona (Edwards 1974). Stripers were first stocked into Lake Mead in 1969 (Roden 1978) with additional plants yearly until 1972. Presently, stripers are found in Lake Mead and the Colorado River below Davis Dam to below Laguna Dam. There is no evidence of established populations in Lake Mohave, but the species may be present. Stripers are believed to travel up the Colorado at least as far as Separation Canyon, and possibly beyond (Carothers and Minckley 1980).

II. Life History

Reproduction

Maturity

Age at maturity is extremely variable. Females usually mature at ages 4-7 (Raney 1952); however, in the Colorado River 3-year old fish may be mature. Edwards (1974) reported that 50 percent of 3-year old females creeled in the river were mature; many 3-year old females in Lake Mead were also mature (Roden 1978). Males mature at 3-5 years (Scofield 1931; Minckley 1973) but 2-year old mature males are known (Raney 1952) and are common in Lake Mead (Roden 1978). Maturity is determined by the color of the eggs and ovaries (Woodhull 1957) with a greenish color signifying maturity and cream colored, immaturity.

Fecundity

Striped bass produce a large number of eggs, the amount increasing with size and age of the fish (Jackson and Tiller 1952). A female increases egg production by 176,000 ova per kg body weight (Lewis and Bonner 1966). A female bass 4 years old and 2 kg in weight averages 68,000 eggs, and a 14-year old, 15.9 kg fish averages 4,536,800 eggs (Jackson and Tiller 1952). Fish in Oregon produced 220,000 ova per kg body weight (Morgan and Gerlach 1950). Females from the Colorado River ranged from 149,142 per kg body weight to 308,085 per kg with a mean of 231,642 per kg (Edwards 1974). Fecundity for Lake Mead is estimated to be similar (Roden 1978). The fecundities for the Colorado River are higher than those from other areas. Mature striper eggs are approximately 0.33-1.0 mm in diameter (Lewis 1962). Ova in the Colorado mature up to 1.35 mm with a mean of 1.02 mm (Edwards 1974).

Spawning behavior

In its natural habitat, striped bass are anadromous spawners, travelling up major rivers to spawn. In the Colorado River, spawning takes place in Lake Mead (in Vegas Wash, the mouths of the Virgin and Muddy Rivers and the head of the lake) (Roden 1978), below Davis Dam (Edwards 1974) and possibly near the All-American Canal (Arizona Game and Fish 1966).

There is no extensive courtship prior to spawning. One female will be accompanied by several males, as many as 10-50 (Merriman 1941). Fish mill about in a circle, splashing water high in the air (Goodson 1966B). The act lasts only a minute, the fish quickly disperse (Morgan and Gerlach 1950). Mature fish may not spawn each year (Raney 1952).

Fish begin spawning on rising water temperatures at 14.4-15.6°C with a peak at 15.6-19.4°C. Spawning ceases at 21°C (Dickson 1957; Talbot 1966; Calhoun 1950; Raney 1958). Spawning in Lake Havasu runs from early April until mid-June (Edwards 1974). Sudden temperature drops or storms will halt spawning (Calhoun 1950; Talbot 1966).

Spawning can only take place in areas with current. The eggs are broadcast into the water and have a specific gravity of 1.005 and are semibuoyant. In order to hatch, they must remain suspended in the water column.

Embryo development

Following spawning, the eggs float downstream. Time till hatching is dependent on water temperature.

Eggs hatch in 70-74 hours at 14.4-15.6°C (Surber 1957), and 60 hours at 17.8°C (Goodson 1966). Raney (1958) gave a hatching time of 48 hours at 17.9°C, similar to Albrecht's (1964) 48 hours at 15.6-17.8°C.

Fry and Juveniles

Approximately 10 days after fertilization, the young reach the postlarval stage (Pearson 1938). At 1.3 cm, the fry form small schools and move inshore.In coastal rivers, young stripers will remain in fresh or brackish water areas for 2 years before going to sea (Raney 1952). Within the Colorado River no such movement is possible, instead the young fish move into the reservoirs. Young stripers feed mainly on plankton and aquatic insects then turn piscivorous.

Young stripers grow fastest during late spring and early summer (Edwards 1974). Year classes introduced into the river from California (1961-1965) grew to an average of 15.2 cm in their first year. River-spawned fish (1966, 68, 70, 71) grew a mean of 20.7 cm in their first year. Edwards (1974) discusses this difference in growth rates and attributes it to transplant shock and intra-specific competition among the introduced fry, and adaption to a freshwater habitat. Marine stocks were used in the 1961-65 plants. Second year growth of these fish was rapid and nearly brought them up to the rest of the population. Fish at 2 years old averaged 17.2 cm (Edwards 1974).

In Lake Mead the same growth differential was apparent. Stocked fish averaged 19.6 cm and 37.6 cm at age 1 and 2, while naturally reproduced fish averaged 24.6 and 49.0 cm (Johnson and Roden 1977).

Adult

Age and Growth

Roden (1978) provides a table showing growth rates for several populations of striped bass (Table 7). Growth is density dependent (Chadwick 1966) with best growth occurring in new expanding populations. This may account for the high initial growth rates in the Colorado River.

Adult stripers will weigh from 1.4-13.3 kg (Goodson 1966; Chadwick 1962). Individuals exceeding 13 kg are not uncommon in fresh water (Raney 1952) and ocean-going fish may reach 45 kg (Eddy 1969).

Adult bass grow fastest in summer and early fall, with growth ceasing in late fall and winter. Some year-round growth may occur in the Colorado due to warm winter temperatures (Edwards 1974; Roden 1978; Minckley 1972). The greatest annual growth occurs during the second year, growth increments decrease thereafter. Until age 4, males and females grow at the same rate, females grow faster after age 4 (Edwards 1974).

Feeding

Striped bass are predators. Young stripers feed on plankton and small invertebrates in shallow areas. In their second summer they school and turn piscivorous on small schooling fish (Raney 1952). Striped bass are opportunistic predators. Stripers in a school all feed at the same

Table 7. Comparison of growth rates of striped bass from Lake Mead and other waters and comparison of growth between Lake Mead stocked and naturally produced striped bass.

Area	Reference	Length in centimeters at each annulus 1	2	3	4	5	6	7
Sacramento-San Joaquin Delta, California	Robinson, 1960	(10.9)[1/]	(24.9)	(38.9)	(54.1)	(58.4)	(65.3)	(70.9)
Millerton Lake, California	Wilson and Christenson, 1965	(13.2)[1/]	(30.0)	(42.7)	(55.6)	(67.6)	(77.2)	(86.9)
Atlantic Coast	Meriman, 1941	(12.5)[1/]	(23.6)	(36.6)	(45.0)	(53.1)	(61.1)	(68.6)
Santee-Cooper Reservoir South Carolina	Stevens, 1958	(21.6)[2/]	(39.9)	(50.3)	(58.2)	(65.5)	(72.4)	(77.0)
Kerr Reservoir, Virginia/North Carolina	Domrose, 1963	(13.0)[2/]	(28.2)	(41.7)	(56.1)	(66.8)	(69.9)	(78.0)
Maryland	Mansueti 1961	(13.0)[1/]	(29.5)	(38.6)	(48.3)	(52.8)	(62.0)	
Oregon	Morgan and Gerlach, 1950	---[1/]	(37.3)	(48.3)	(57.9)	(63.5)	(69.1)	
Colorado River Arizona/California/Nevada	Edwards, 1974	(17.0)[1/]	(43.7)	(58.9)	(69.3)	(77.7)	(83.6)	
Lake Mead, Arizona/Nevada (Stocked Fish)	Johnson and Roden, 1977	(19.6)[1/]	(37.6)	(53.8)	(67.8)	(78.0)	(84.3)	(91.4)
Lake Mead, Arizona/Nevada (Natural Fish)	Johnson and Roden, 1977	(24.6)[1/]	(49.0)	(64.0)	(71.9)	(77.2)		

1/ Fork Length
2/ Total Length

from Roden 1978

time, but feeding is not continuous (Raney 1952). Fish are the primary component of the striper diet. In freshwater habitats, culpeid forage fish, such as threadfin shad, are the dominant food (Stevens 1958). When adequate numbers of these fish are absent, stripers will consume crayfish (Johnson 1976), insects (Stevens 1958), or game fish, such as crappie (Domrose 1963). Marine populations utilize crustaceans, annelid worms (Hildebrand and Schroeder 1928) and shrimp (Johnson and Calhous 1952) as well as fish. In Coos Bay, Oregon, trout and salmon fingerlings and fry make up 7 percent of the diet in April, May and June (Morgan and Gerlach 1958).

In Lake Mead and below Davis Dam, threadfin shad are the primary forage. Striped bass below Davis Dam feed heavily on shad that come through the turbines (Edwards 1974). Newly stocked rainbow trout are also consumed by stripers. Tagging studies revealed 20 bass ate 24 trout (18 tagged) within 13 days of stocking. Predation on trout declines as the fish become accustomed to their new environment (Edwards 1974). Trout also provide striper forage in Lake Mead (Nevada Department of Fish and Game 1980; Johnson 1976; Nevada Fish and Game 1976A) making up as much as 23 percent (Johnson 1976). Again, trout are most vulnerable just after stocking. Other fish occasionally eaten include carp, green sunfish and largemouth bass (Edwards 1974).

Movement

Stripers are very active fish, adults move freely and rapidly throughout the reservoirs. In Lake Mead, fish travelled 5.6-6.4 km within hours

(Nevada Dept. Fish and Game 1976A). Fish are more active at night (Bayless 1969). Feeding takes place just after dark and just before dawn (Hollis 1952) Adults migrate up rivers to spawn, the distance travelled is dependent on environmental factors. Marine populations often ascend great distances in coastal rivers before they spawn.

In Santee-Cooper (S.C.), stripers travel 80-96 km to spawning areas (Talbot 1966). In rivers with slower velocities, for example the Roanoke River below Kerr Reservoir (VA.) bass travelled 217 km to spawn (Dickson 1957).

Physical factors

Striped bass probably have similar environmental tolerances to pH, dissolved oxygen and alkalinity as other fish species. Based on the natural range of the species, it can be assumed that they can tolerate a wide temperature range, existing as they do from cold Canadian Rivers to Louisiana bayous (Pearson 1938). Stripers are extremely euryhaline, able to thrive in fresh to saline ocean water.

III. Interactions

As a major predator, striped bass exert a considerable influence on populations of other fishes. While this impact is primarily felt by the threadfin shad forage population, when shad, or other suitable forage species are not present, game fish may be preyed upon. Stripers may also compete directly with other game fish from the limited food resource.

Young stripers also utilize the same foods and shallow water areas as the young of other game fish, but no direct competition has been noted. Striped bass populations, utilizing an underused forage base, can expand their populations beyond the capability of the forage fish to support them. This was demonstrated in Santee-Cooper Reservoir in South Carolina where the striper population declined by 30-50 percent after the forage base was decimated (Stevens 1964). The same situation could develop in the Colorado River. There are signs that stripers in Lake Mead may be having some feeding problems (Arizona Game and Fish 1980) but there is no specific data on the causes or possible solutions to the problem, if there is one. A similar situation may exist in the lower river, in the Imperial Division. Abundant striper and flathead catfish populations are depending on a forage base that may not hold up (Arizona Game and Fish Dept. 1976).

The presence of striped bass may have a detrimental effect on salmonid populations. Stripers prey on trout and may be one of the causes for the decline of the Lake Mead trout fishery (Nevada Dept. Fish and Game 1976) but there are no studies to evaluate this. It is believed that the presence of stripers in Lake Mohave would impact that important trout fishery but the extent of possible impacts are unclear. Similar concern exists if the species should make its way through the Grand Canyon to Lee's Ferry and impact that trophy trout fishery. In addition, there may be impacts to native fish populations in the Grand Canyon itself.

IV. Fishery

Striped bass provide a substantial fishery on the Colorado River. Trophy sized, hard-fighting and good eating, stripers are eagerly sought after by anglers.

Stripers began to show in the creel in 1964 below Davis Dam (Arizona Game and Fish 1965) but successful fishing began in 1966. Each year angling effort increased, but until the use of anchovy bait replaced artificial lures, catches were not high (Edwards 1974). Stripers provided 20 percent of the catch below Davis Dam in 1977 (Arizona Game and Fish Dept. 1977B).

Striped bass were introduced in Lake Mead in 1969 and entered the harvest in 1971 as 2-year olds (Roden 1978). Angler effort remained low until 1976 when it reached 11 percent of the total. Catch was still low, only 1.4 percent, and remained low until 1979, when stripers made up 40 percent of the catch as compared to 4 percent in 1978 (Roden 1978; Nevada Department of Fish and Game 1980).

LARGEMOUTH BASS

I. Introduction

The largemouth bass, Micropterus salmoides Lacepede has been widely introduced into the lower Colorado River drainage and provides the basis for an extensive sport fishery. There are two subspecies, the northern largemouth (Micropterus salmoides salmoides) and the Florida largemouth (Micropterus salmoides floridanus). Most stockings within the project area have been of the northern subspecies.

II. Life History

Reproduction

Maturity

Sexual maturity in largemouth bass is size dependent. Females reach maturity at 25 cm TL (weight 200 gms) and males mature at 22 cm TL (weight 160 gms) (James 1939). Age at time of first spawning varies from 3-4 years in northern areas (Heidinger 1975) to 1 year in some southern states (Swingle and Smith 1950). In Lakes Mead and Mohave, most bass spawn at age 2, with all mature by age 3 (Jonez and Sumner 1954).

Fecundity

Ovaries of a mature female bass begin to develop eggs in the late summer or early fall (Heidinger 1975). At time of spawning, the egg mass may make up as much as 10 percent of the total body weight (Jonez 1942).

The mature ovaries contain between 2000-145,000 eggs depending upon the size of the fish (Carlander 1953; Bishop 1968). The number of eggs per pound of fish varies from 4,000 to 80,000 (8,800-176,000 eggs/kilogram) (Heidinger 1975). Not all eggs are mature at time of spawning. Immature eggs remain in the ovary after the reproductive period and are reabsorbed. Mature eggs are 0.75-1.56 mm in diameter (Heidinger 1976).

The testes of a mature male make up only one half of one percent of body weight (James 1942). The sperm have an ovoid head 2 microns long and a 20 micron tail (Carr 1942). Sperm are viable for only a minute or so after being shed.

Spawning behavior

Largemouth bass are substratum spawners. The male bass construct and guard a nest area. Nests are a depression, roughly circular, with a diameter twice the length of the bass (Carr 1942). Depth of the depression is dependent on the hardness of the substrate.

Nests are located along shorelines in sheltered coves. Water depth will vary from 6 inches to 18 feet. In Lake Mead, depths of the nest have varied from 3 feet (1 m) to over 15 feet (4.57 m) (Jonez and Sumner, 1954); and in 1973, nesting was observed by divers at 24.5 feet (7.5 m) (Allan and Romero, 1975). In Lake Mohave, nest depths have been observed to vary from 2 feet (.61 m) to over 10 feet (3.0 m) (Jonez and Sumner, 1954) with a mean water depth of 5.9 feet (range 2-15 feet) (1.82 m, range .61-4.57 m) (Nevada Department of Fish and Game 1980). Nests constructed later in the spawning period are in deeper water than those from early in the year. Substrates vary considerably. Bass in the Lakes Mead and Mohave have been documented spawning over bedrock, tamarisk rootlets, sessile filamentous algal mats, rocks, rubble and gravel. In other areas, sand, gravel, roots and aquatic vegetation provide acceptable spawning areas (Emig 1966). Nests are usually in proximity to large rocks, ledges or submerged vegetation, features which aid in sheltering the nest (Jonez and Sumner 1954; Nevada Fish and Game 1974). Bass will not nest on silt bottoms (Robinson 1961) but will utilize areas swept clear of fine particulate material (Allan and Romero 1975). Nests are built on slopes from 0-50^{o} (Allan and Romero 1975).

Bass will defend both the nest and the surrounding territory from intrusion. The usual territory is a 2m diameter circle with the nest in the center (Carr 1942), however, territories may be larger. In areas with abundant cover that reduces the likelihood of male bass seeing each other (Breder 1936), territories may be less than 2 meters. Spawning is believed to take place near dusk or dawn (Carr 1942). Once the male completes the nest, he will leave it for short periods in search of a ripe female. When a ripe female comes to the nest, the male induces the female to lay her eggs. Both fish undergo vivid color changes. They swim together over the nest and eggs and milt are released simultaneously. This process may be repeated several times by the same pair before the female leaves. Female bass may spawn with more than one male, and a male bass may entice more than one female to his nest (Heidinger 1975). Successful bass nests may have 5,000-43,000 eggs (Snow 1971; Kramer and Smith 1962).

In addition to fanning the eggs, the adult male bass guards the nest against egg predators such as the bluegill, Lepomis macrochirus. Other organisms, the predatory snail (Viviparus georianus) (Eckblad and Shealy 1972) and aquatic insects are often ignored by the guardian bass (Shealy 1971). Golden shiners (Notegomus crysoleucas) and lake chubsucker (Erimyzon sucetta) are allowed to lay their eggs in a bass nest (Carr 1942, Kramer and Smith 1960). Agressive protection of the nest is essential for successful fry production (Allan and Romero 1975). Males do not eat while they are defending the nest.

Largemouth bass begin spawning activity in the spring at water temperatures 15-24^{o}C. Maximum activity occurs around 19-20^{o}C (Heidinger 1975, 1976). In the lower Colorado River, spawning takes place in late March through July (Arizona Game and Fish Department 1961) with most spawning completed by June with a peak in mid April-May (Nevada Department of Fish and Game 1980).

Spawning bass avoid turbidities over 75 ppm (Buck 1956); salinities over .25 ppt (Tebo and McCoy 1964), pH's below 5 (Swingle 1949) or above 10 and dissolved oxygen below 1.5 ppm.

Declining water levels during the spawning period can destroy bass nests. Storms and wave action on unprotected nests also result in nest destruction. A decline in water temperature of 4-6^{o} C can cause erratic behavior in the guardian male and it may abandon the nest (Allan and Romero 1975).

Embryo Development

The fertilized eggs are yellow to orange, adhesive and 1.4-1.8 mm in diameter. The male bass positions himself over the nest and fans the eggs keeping them clear of silt. At 10°, 18° and 28°C, bass eggs hatch at 317, 55 and 49 hours respectively (Badenhuizen 1969). Optimum developmental temperature is 20°C (Badenhuizen 1969) with 10°C (Kramer and Smith 1960) and 36.8°C (Carlander 1977) being the lower and upper lethal limits. Temperatures below optimum result in slower development and a concurrent increase in the chance of disease attacks (especially of the fungus Saprolegnia) and predation wiping out a nest (Allan and Romero 1975). Embryos are very sensitive to temperature shock (Eipper 1975). Embroyos developed and hatched at dissolved oxygens of 1.0-1.3 mg/l at 15°-25°C, but survival was low at concentrations less than 2.0-2.8 mg/l at 15°-25°C. Dissolved oxygen was especially critical during hatching. During these periods, oxygen demand increases dramatically as the embryos move about (Dudley and Eepper 1975) and mortalities can be quite high. Any movement of the eggs during incubation, such as caused by wave action, may also result in low embryo survival.

Fry/Larvae

Larvae bass are 3-5.5 mm TL at hatching (Carr 1942) and during the critical development period (until they reach 10 mm) they remain on the bottom of the nest. Post-hatching developmental times are temperature dependent (Table 8). At 20°C the mouth forms at 192 hours (post-fertilization), the larvae become free swimming at 240 hours and the yolk sac is absorbed by 312 hours (Laurence 1969).

Bass fry must eat within 6 days of becoming free swimming. In observations (Laurence 1969), only 74 percent did begin to eat. Fed fry are more active than non-fed fry. In a comparison of swimming speed, fed fry attained 4.0 cm/sec while non-fed fry could only reach 1.5 cm/sec (Laurence 1972). Initially, 2-8 days post-free swimming fry only feed during the day. At night they rest on the bottom (Laurence 1971).

In Lakes Mead and Mohave, zooplankton are the primary food of bass fry. Fry 8-12 mm TL feed on Cyclops and Bosmina. Larger fry (16-20 mm) feed on larger Daphnia. A wider variety of food items is found in 12-16 mm fry (Baker and Burk 1976).

Table 8. Development time of eggs and sac fry vs. water temperature 1/

Temperature	Eggs in Nest (days)			Sac fry in Nest (days)		
Range	High	Low	Avg.	High	Low	Avg.
55 - 60°F. (12.8-15.6°C.)	8	4	5.4	13	3	7.2
60 - 65°F. (15.6-18.3°C.)	7	3	4.7	13	3	7.2
65 - 70°F. (18.3-21.1°C.)	4	3	3.1	11	4	6.7
70 - 75°F. (21.1-23.9°C.)	4	3	3.1	7	5	6.0

1/ Nevada Department of Fish and Game 1974.

Bass larvae remain near the nest, relying on the male bass for protection. Upon becoming free swimming fry form schools called "balls" or "swarms" and are still under the male's care. During the day the school is roughly spherical, about one meter in diameter. Fry move freely in the school feeding on zooplankton. As a whole, the school moves little, remaining in shallow water near the bottom. At night, the fry rest on the bottom in a compact mass (Edwards 1974).

Larvae bass will develop in waters 15-30^{o}C. with an optimum temperature near 27^{o}C. (Strawn 1961). Temperatures below 10^{o}C and above 36^{o}C. are lethal (Kramer and Smith 1960). Low sublethal temperatures can result in deformity, stunting or erratic behavior (Eipper 1977).

Dissolved oxygen is critical until the larvae begin opercular movements at day 7 (at 20^{o}C). Dissolved oxygen levels of 1-2 mg/l are lethal within 1 hour (Spoor 1977). A concentration of 2.5 mg/l at 25^{o}C. was lethal in 3 hours. Sublethal oxygen concentrations will cause increased larval activity resulting in vertical displacement ("surfacing") from the nest. Dissolved oxygen concentrations of 5 mg/l at 23-24.5^{o}C. caused surfacing and 4 mg/l at 20^{o}C. resulted in increased activity (Spoor 1977). Optima for other physical factors are similar to those reported for juveniles.

Juveniles

Juvenile bass (40-150 mm TL) grow quite rapidly. In early stages they feed on pelagic prey, larvae and adult insects and crustacea (Emig

1966). At about 50 mm TL, fish become part of the diet (Kramer and Smith 1962) and rapidly increase in importance as bass reach 100 mm TL (Emig 1966). Larval fish of several species are consumed. Juvenile bass will consume prey 10-40 mm TL (Applegate and Mullen 1966) depending on the size of the bass. There is some evidence that the prey species available may influence the time at which bass begin to eat fish. In a California lake, Mississippi silversides were consumed by bass 40-60 mm FL while bluegill _Lepomis macrochirus_ were consumed only by bass over 60 mm (Moyle and Holtzhauser 1978). Silversides are slender fish and may be easier for a small bass to swallow.

Juvenile bass leave the nest area in schools and seek cover. The male bass no longer protects them, and schools disperse. Good cover in the form of drowned terrestrial or aquatic vegetation is essential during this time.

Juveniles tend to select somewhat warmer water than adults. Optimum temperatures are 29-32°C with lethal temperatures of 5.2°C and 38.9°C (Trembley 1960; Carlander 1977). Dissolved oxygen levels between 2.5-4.0 mg/l (at 25°C) are satisfactory with 8 mg/l O_2 being optimum. Levels below .78 mg/l are lethal (Moss and Scott 1961; Stewart et al 1967; Bulkley 1975). Salinites under 3.5 ppt (Tebo and McCoy 1964) and turbidities under 100 ppm (Buck 1956) are optimum for survival and growth. Preferred pH levels are between 6 and 9.5 (Calabrese 1969) with lethal pH's of 3.7 and 11 (Calabrese 1969; Bulkley 1975).

Survival of Young Bass

Survival of young-of-year largemouth bass is dependent on several factors. Optimum temperatures and water conditions during early embryonic development, low incidence of *Sapnolegnia* fungus infestations of nests, and proper parental care will insure maximum hatching success. Once the fry begin to feed, there must be adequate food available.

A case in point can be made using two successive year classes in Lake Mead. The 1973 year class was successful. Zooplankton were abundant, comprising 50-100 percent of sample volume with cladocera dominating the zoo plankton segment (70-80 percent). In 1974, the bass had very low survival, zooplankton at time of first fry feeding made up 15-20 percent of sample volume and copepods made up 70-80 percent of that volume (Allan and Romero 1975).

Proper size of food is also important in later stages to permit rapid growth and condition. Slow growing, poor condition fish are more subject to disease and predation.

Predation is a normal component to fry mortality. However, high predation rates can result from several causes. In areas lacking adequate forage species, larger bass will prey heavily on their own species. Yearling bass were documented as a major predator on young of year bass under 5 cm TL (Nevada Game and Fish 1968). Larger fry and fingerlings also prey on late spawned bass. Bass 2.5-5.0 cm will prey on .65-.19 cm bass, 7.5

cm bass will prey on 2.5 cm fry and 15 cm bass will prey on anything smaller (Allan and Romero 1975). Bluegill and black crappie are also predators on .12-.20 cm bass (Beland 1954) as are adult bass.

Predation rates are directly dependent on one other major factor, cover. Once young bass leave the protective care of the male, they require good cover in the form of established aquatic plant beds or recently (1 year or less) submerged terrestrial vegetation. In addition to providing an escape refuge, these terrestrial plant areas support a higher number of food organisms available to the young fish (Allan and Romero 1975).

Adult Stage

Age and Growth

At the end of the first year of life largemouth bass reach 5-35 cm in length. This variation is strongly correlated with food availability (Heidinger 1975), but length of growing season is also important. In Lake Havasu the 1965 year class was 10-22.5 cm TL as yearlings in 1966 and in the lower Colorado, the 1965 year class were 10-17.5 cm in 1965 and 20-30 cm as yearlings (Cross 1967). Bass first appear in the creel at 18 cm (Heidinger 1976). In the average bass population, the majority of the fish are under 35 cm TL (Heidinger 1976). In one large reservoir, 44 percent were between 2-10 cm, 42 percent between 12-23 cm and 14 percent were over 23 cm (Hayne, Hall and Nichols 1967).

Population densities of 120-240 adult fish/ha are strong bass populations. Populations of stunted 20-25 cm fish can result at densities over 240 fish/ha. Weak bass populations consist of a few large individuals (Heidinger 1975). The mean standing crop of largemouth bass in 170 U.S. reservoirs (averaging 15,000 acres) was 8.9 lb/acre (10 kg/ha); standing crops of 20 lb/acre (22 kg/ha) were found in small lakes and backwaters. Large populations may exceed 58 lb/acre (60 kg/ha) (Jenkins 1975).

Bass may live to as old as 15 years (Bennett 1937) but ages of 6-7 years are more typical. There is some evidence to indicate that slow growing bass live longer than fast growing bass (Heidinger 1976) and bass in northern areas live longer than those in southern areas (Carlander 1977). Male bass do not live as long as female bass (Padfield 1951).

Feeding

Largemouth bass are predators, eating anything small enough to be swallowed (Minckley 1973). Bass require anywhere from 25 percent (90 g bass) to 3.0 percent (450-900 g bass) of body weight in food per day (Lewis et al 1974). Bass do not feed while spawning, at D.O. less than 1 mg/l (Snow 1961) and at temperatures above 37° C. and below 5°C. (Markus 1932). Amount of food eaten declines with temperature; bass eat three times as much food at 20°C than at 10°C. (Hathaway 1927).

The size of forage utilized increases with bass size (Heidinger 1976). Adult bass are piscivorous. Crayfish, if available, are extensively utilized (Heidinger 1976). Bass in Lake Mohave utilize bluegill, green sunfish, small carp and other bass (Jonez and Sumner 1954). Since their more commonly found in waters 15 to 20 feet (4.6 to 6.1 m) in depth. In August and November, bass were frequently observed at depths over 40 feet (12.2 m) (Lockard et al 1971 in: Heidinger 1976), and occasionally bass have reached depths of 100 feet (30.5 m) (Jones and Sumner 1954). The young of the year also have been observed moving into deeper water. During late May through July of 1973 and 1974 in Lake Mead, fingerling bass were observed at depths of 25 to 60 feet (7.6 to 18.3 m) (Allan and Romero 1975). In Lake Mohave, the same type of vertical movement occurs, and bass have been found as deep as 60 feet (18.4 m) (Jones and Sumner 1954).

Physical Factors

Largemouth bass populations thrive in shallow (less than 6 m) slow moving (less than 15 cm/sec) mud bottomed lakes and streams. They are also abundant in protected areas of large lakes and reservoirs and some rivers (Carlander 1977). In the Colorado River, they are more abundant in backwater areas than in the main river channel although they move freely between the two areas (Minckley 1979).

Bass require cover. Drowned terrestrial vegetation, aquatic vegetation (Emig 1966) artificial reef (Prince et al 1975) or brush shelters (Vogele and Rainwater 1975) are all used extensively.

Adult bass optimum temperatures are between 25-30^{o} C (Coutant 1975). Temperatures below 15^{o} C and above 32^{o} C are detrimental; lethals are 5.2^{o} C and 38.9^{o} C Oxygen levels of 1 mg/l are usually lethal (Moss and Scott 1961) but sub-lethal oxygen concentrations result in physiological stress to the fish. Blood pH declines (indicating laetic acid build up from anaerobic respiration) and metabolism slows (Cech, Campagna and Mitchell 1979).

Adults can survive turbidities as high as 100,000 ppm (Wallen 1951) but concentrations less than 100 ppm are more favorable (Buck 1956). Optimal salinities are less than .6 ppt. Those less than 3.6 ppt are acceptable and occasionally salinities in excess of 20 ppt will be tolerated (Bailey et al 1954; Tebo and McCoy 1964; Bulkley 1975).

III. Interactions

From the time largemouth bass begin to consume fish, they have a considerable impact on the fish species utilized as forage. In some cases, as with fathead minnows (*Pimephales promelas*) and red shiners (*Notropis lutrensis*) in California, the forage species could not maintain adequate populations in the face of heavy predation (von Geldern and Mitchell 1975). Fry and fingerlings of forage species, including young bass, are very vulnerable to predation. Bass will utilize sunfish, crappie, carp (Beland 1954), minnows and catfish (Heidinger 1976) as food. In good bass areas, fry survival of these species is very low.

The forage species can also have negative impacts on young bass. High density mixed sunfish stocks put in small ponds with bass could surpress or eliminate bass spawning; even before the bass completed nest construction (Smith 1976). Even if bass spawn successfully, numerous sunfish can successfully raid the guarded nest. Bluegills (Heidinger 1976), green sunfish and black crappie (Beland 1954) have been documented as predators on bass fry.

Fry of most game fish species rely heavily upon zooplankton for the first food. As previously mentioned, bass fry must eat within 6 days of becoming free swimming. If zooplankton is limiting, fewer fry will survive. Fry of early spawning species will have an advantage. Largemouth bass spawn before most other centrarchids (except crappie and smallmouth bass) (Heidinger 1976). By the time sunfish fry are available, the young bass have grown enough to turn piscivorous (Weaver 1971).

Threadfin shad (Dorosoma petenense) have been widely introduced as bass forage. While they are extensively utilized by all sizes of bass, there is evidence that their presence surpresses early bass growth. Threadfin shad are planktivorous throughout life and thus may directly compete with young of the year bass (von Geldern and Mitchell 1975; Miller 1971). However, growth rates for young of the year bass in Lake Mead have increased considerably since shad were introduced (Roden 1978).

Interactions between fish species are complex and for the most part, not well known or definitely quantified. Some general ideas on food interactions, predation and behavioral impacts can be given, but detailed information on these and other factors is not available.

IV. Fishery

For many years the largemouth bass was the premier sport fish in the Colorado River. The bass fishery that developed in Lake Mead after the closing of Hoover Dam was one of the finest in the west. Bass made up 78 percent of the Lake Mead catch in 1962 (Nevada Department of Fish and Game 1962), but had declined to only 9 percent of the catch in 1979 (Nevada Departemnt of Fish and Game 1980). The natural aging of Lake Mead caused, in part, the decline of the quality of the fishery and the introduction of rainbow trout (Salmo gairdneri) and, especially the striped bass (Morone saxitilis) to the fishery of the river diverted angler attention from the bass.

Bass are still an important component of the fishery in the lower Colorado, especially the Imperial Division backwaters. However, there has been a decline in the quality of the fishery in some areas (Martinez Lake - Arizona Coop. Fish Unit, no date) while the quantity of fish remains high. Despite these changes, the largemouth bass remains an important component in the fish fauna of the Colorado River.

BLACK CRAPPIE

I. Introduction

The black crappie, Pomoxis nigromaculatus was introduced into Lake Mead during the mid 1930's. The introduction was probably accidental (Roden 1978) but the fish spread throughout the river. The original range of this centrarchid was from Quebec to Florida and west as far as Montana (Scott and Crossman 1973).

II. Life History

Reproduction

Maturity

Crappie may be sexually mature at 1 year (La Rivers 1962) but most mature at 2-3 years at lengths of 18-23 cm (Huish 1954; Sigler 1959). Age is more important to sexual maturity than size, stunted adults spawned at 10 cm in length (Trautman 1957).

Fecundity

Crappie are extremely prolific. Small fish, 113-226 gm, produced from 11,000 to 48,000 eggs. Larger fish, 567-680 gm can produce from 77,000 to 188,000 eggs (Vessel and Eddy 1941). In Lake Mead, 30-33 cm fish produced an average of 60,000 eggs (Jonez and Sumner 1954). Ovaries develop in the fall (Morgan 1951). Mature eggs are 0.93 ± 0.082 mm in diameter, this is smaller than eggs of largemouth bass, bluegill, or warmouth. Egg size does not increase with size of the female (Merriner 1971).

Spawning behavior

Like other centrarchids, crappies build and defend nests. Nests are constructed in water .9-2.4 m in depth (Roden 1978) but nests a few cms (Sigler and Miller 1963) to 6 m deep (Eddy and Surber 1947) are known. Nests are found on level to steeply sloping ground (Jonez and Sumner 1954) and in close proximity to large rocks, boulders and submerged brush. In Roosevelt Lake, crappies spawned in areas of dense brush (Ercole 1966). Since most spawning takes place on or at the base of vegetation, this may be a limiting factor for crappie reproduction (Carlander 1977). Few crappie nested in areas devoid of brush in Roosevelt Lake (Ercole 1969). Gravel, rock and sand are the preferred nesting materials, but the substrate is often muddier and softer than used by other centrarchids (Eddy and Surber 1947).

Smaller males move inshore to establish territories before the larger males (Ginnelly 1971). Nests are bowl shaped depressions about 25 cm in diameter (Minckley 1973), and may be quite close together. As many as 30 nests have been counted in a 9 m^2 area (Ginnelly 1971).

Final construction of the nest does not occur until after the male has attracted a ripe female to his territory. Using rapid, sideways sweeping motions, he creates a small depression. The male then swims around the female, bumping at her sides and belly to encourage egg deposition. After the eggs are shed, the female leaves and the male then fertilizes the eggs (Ercole 1969). Males guard the nest aggressively and will dart out to snap at any fish or object that comes too close (Sigler and Miller 1963).

Crappie spawn in the spring, beginning in March and ending in late April or May (Jones and Sumner 1954; Arizona Game and Fish Department 1961). Spawning takes place at temperatures berween 12.8-18.3° C. with peak spawning occurring at 13.9-16.7° C. (Jonez and Sumner 1954). Larger, older fish may spawn earlier than smaller, younger fish (Whiteside 1964). In Roosevelt Lake in 1968, there were two distinct spawns, one in early June, the other in late October (Ercole 1969).

Crappie tested at oxygen concentrations of 2.5 ppm to saturation reproduced successfully at all concentrations tested. There was no effect on the number of embryos, viability, hatching success, or survival through fry swim-up. However, fish at low oxygen concentrations began spawning behavior earlier, thus at lower temperatures and ended the spawning period sooner (Siefert and Herman 1977).

Embryo development

Fertilized eggs are slightly less than 1 mm in diameter, whitish, demersal and adhesive (Scott and Crossman 1963). The median hatch was 57.5 hours at 18.3° C. with a range of 48.1-67.8 hours (Merriner 1971).

Fry and Juveniles

Fry are guarded by the male for a few days, then desert the nest (Scott and Crossman 1963). The fry form a tight "ball" or "swarm" and remain in the school through the fingerling stage (Jonez and Sumner 1954). The schools move into the limnetic zone and remain there. Young of the year crappie are often caught in mid water shad trawls and in the 1962 Vela Uniform test explosions in the Vegas Wash area of Lake Mead, over one million young crappies were killed by the underwater explosions (Nevada Fish and Game 1962). The combination of limnetic distribution and earlier spawning times aid in protecting young crappies from bass predation. However, if a strong age 1 bass population exists, these fish prey heavily on young of year crappies (Swingle and Swingle 1967). Rising water levels which inundate brush provide protection for young crappies while they are in the littoral (Ercole 1969). Populations of small aquatic organisms are also stimulated by the freshly drowned vegetation, providing a food source for the young fish (Roden 1978). Slowed growth and stunted populations may be the result of several years of spring drawdowns (Goodson 1966).

Young crappies feed on zooplankton and aquatic insects. Copepods and chironomid larvae were consumed by 2-week old crappie, cladocerans at 3 weeks, ostracods at 6 weeks and oscillatorial algae at 10 weeks. At 13 weeks all items were still taken (Burris 1956). Crappie become piscivorous very early. Fish 5-7.5 cm will prey on smaller fish (Huish 1957).

Juvenile crappie grow rapidly and reach 2.5-7.5 cm by October (Trautman 1957). Lengths vary greatly, growth is very dependent upon adequate forage (Goodman 1966). Age I fish may range in size from 1.5 cm FL (Goodman 1966) to 20.0 cm (Ercole 1969). The 20 cm fish, from Roosevelt

Lake, grew extensively over the winter. The diet of juvenile crappies is similar to that of adults.

Adults

Age and Growth

Black crappie are relatively short lived (Goodson 1966) with few fish reaching age 6 (Jonez and Sumner 1954; Hall et al 1954; Stevens 1959). In Lakes Mead and Mohave, crappie 4 years old and less made up the bulk of the population (Nevada Fish and Game 1976a, 1976b).

Crappie will average 30 cm in length and 450-675 gms in weight (LaRivers 1962; Sigler and Miller 1963). Mean total lengths for western waters are: Age I - 8.5 cm; Age II - 15.6 cm; Age III - 20.6 cm; Age IV - 23.4 cm; Age V - 24.1 cm; Age VI - 20.1, and Age VII - 19.2 cm (Carlander 1977).

Growth rates are affected by several environmental parameters. Water level fluctuations lead to slow growth and stunting (Goodson 1966; Ercole 1969). Lack of suitably small (1-2.5 cm) forage fish, (Beland 1954) will also result in a slow growing, stunted population (Crowley 1954). Good cover is also an important factor in growth and survival of crappies (Hall et al 1954) and may be a necessity. California waters without good cover had poor fisheries while those with good cover had good fisheries (Goodman 1966). The usual growing season lasts 5-6 months with best growth occurring in a 6-8 week period (Sigler and

Miller 1963). Growth is very rapid in new reservoirs (Carlander 1977) and more rapid in thermally stratified reservoirs than unstratified (Mayhew 1960).

Crappie populations tend to cycle. One large year class tends to dominate the population for several years. These fish prey heavily on their own young and the young of other fish, thus keeping populations of other year classes low. Fishing is often good during this time. Within 2 years the dominant year class is depleted and enough young crappies survive to provide material for another dominant year class (Crowley 1954; Thompson 1941; Sizer 1961).

Feeding

Crappie feed mainly at night or in the early morning (Ercole 1969). Plankton, especially zooplankton remains an important food item, comprising as much as 50 percent of the diet (Carlander 1977; Jonez and Sumner 1954). Small fish, including centrarchid fry, (Jones and Sumner 1954), threadfin shad (Deacon et al 1972; Ercole 1969; May and Thompson 1974) and numerous other species (Carlander 1977) form an important part of the diet. Aquatic insects are also heavily utilized (Goodman 1966).

In lakes with threadfin shad, crappies utilize this species extensively as forage. Crappie diets in Lake Powell changed from a zooplankton dominated diet in summer and small centrarchid dominance the rest of the year, to one dominated year round by shad. Crappie 17.6-25.0 cm had fed equally on zooplankton and young fish, switched to a predominately shad diet after threadfin were introduced in 1968-1969 (May and Thompson 1974). Threadfin shad provide 80 percent of the diet in Roosevelt Lake (Ercole 1969).

During the spawning season, male crappies may undergo a dietary shift. Data from Roosevelt Lake showed that from March-June, male crappies fed on invertebrates while females continued to feed on shad. (Ercole 1969).

Movement

Even as adults, crappies are schooling fish and seem to prefer open, limnetic waters (Sigler and Miller 1963). Crappie come inshore in the spring to spawn, then return to deep water, often in excess of 15 m, in the summer and 30 m in winter (Jonez and Sumner 1954). The fry move into deep water soon after hatching and schooling. Younger fish concentrate in the silt bottomed river mouths in Lake Mead from late spring to fall when they moved to deeper water (Jonez and Sumner 1954).

Crappie are wanderers. Tagging experiments in Lake Mead recovered only one fish but it was 16.1 km from the release site (Jonez and Sumner 1954). In TVA reservoirs, an average of 8.7 km from release site was found (Sigler and Miller 1963). Crappie may also have a home ground for use during the day and leave it at night to feed (Ercole 1969).

Phycial factors

Crappie are warm water fish that prefer water temperatures between 24-30.5^{o} C (Neill and Magnuson 1974) with a maximum survival temperature of 34^{o} C (Trautman 1957). Black crappie dominate over white crappie in waters pH 7 or less (Toole 1950 in Goodson 1966a) but also do well in Lake Havasu where pH exceeds 8 (Goodman 1966). Maximum recorded salinity is 2 ppt with limits of 900 ppm total alkalinity, 250 ppm carbonates and 200 ppm potassium and sodium (McCarraher 1971). Crappie do not tolerate turbid waters (Neal 1963) and require some sort of cover (Goodman 1966).

III. Interactions

Crappie, like largemouth bass, is a piscivorous centrarchid. There are indications that these two species may compete for the same food resource (LaRivers 1962) and this is a source of concern for managers. Crappies also prey heavily on centrarchid fry, including fry of the largemouth bass. The presence of dominant year classes of crappie can decimate fry populations. Small crappie are preyed on by bass, but because of the limnetic habit of the species, they are not readily available except to age 1 bass while the fry are still on the nest.

The presence of planktivorous forage species such as threadfin shad and Mississippi silversides, may also influence the growth and survival of crappie. Since all age classes of crappie rely on zooplankton to some degree, a scarcity of zooplankton will slow growth, and in young of year fish, could markedly decrease year class strength. In California, juvenile black crappie growth was depressed in the first and second year while third year growth was enhanced by the introduction of Mississippi silversides, Menida audens (Hiram, Moyle and Garrett 1976).

IV. Fishery

Crappie are a very popular game fish in the Colorado River. In Lake Mead they currently make up about 25 percent of the sport catch. They are much less important in Lake Mohave where they average about one percent (Roden 1978). In lower river areas they are important in the Topock and Imperial Divisions (Arizona Game and Fish creel census data). Crappie are more actively sought by anglers in the lower river, most of the Mead catch is from indiscriminate anglers, especially in Callville Bay (Nevada Department of Fish and Game 1980). Fishing for crappie is very seasonal, most fish are caught in the spring during the spawning period.

BLUEGILL

I. Introduction

The bluegill sunfish, Lepomis macrochirus Rafinesque is a widely introduced sport fish that also provides forage for larger, predatory game species. Native to the eastern United States, bluegill can now be found throughout the West in lakes, reservoirs and rivers, the result of stocking during the early 1900's.

II. Life History

Reproduction

Maturity

Bluegill reach sexual maturity at 2-3 years of age (Lagler 1956). There are individuals in some areas that spawn at 1 year and 4-month old fish from a fast growing Alabama population were found to be mature (Swingle and Smith 1950).

Fecundity

Bluegill are extremely prolific. Egg counts range between 2,360 in small fish (Ulrey et al 1938) to 15,000-58,000 in 17.8-22.9 cm fish (Eddy and Surber 1943). Carbine (1940) estimated a production of 6,610,000 fry in a 15-acre lake.

Spawning behavior

Like other centrachids, bluegill males build nests and defend a spawning territory. Unlike largemouth bass, they are gregarious spawners, nests are often quite close together. Up to 500 nests were observed in a spawning colony in Alabama (Swingle and Smith 1950). On Lake Mead, as many as 60 nests were located in a 60 sq. ft. area (Jonez and Sumner 1954). Nests are constructed on a variety of substrates and locations. Mud (Carbine 1940), sand, and gravel (Swingle and Smith 1950) are used as well as organic material. Nests may be located near cover, such as boulders or vegetation along sheltered coves or exposed shorelines (Jonez and Sumner 1954). Size of the nest varies from 20-61 cm in diameter and 5-15 cm in depth (Roden 1978). Nests are found between .6-1.8 in depth (Swingle and Smith 1950). Jonez and Sumner (1954) reported nests at 3.1 in Lake Mead. Nest sites are on level, or gently sloping bottoms.

Once the nest is constructed, the male awaits the arrival of ripe females. After a brief courtship, spawning occurs. Several females may lay their eggs in the same nest (Snow et al 1960). Fish may spawn more than once a year (Estes 1949).

Reported spawning temperatures for bluegill range from 15.6°C to 26.7°C (Rousenfell and Everhart 1953). Spawning in Lake Mohave begins at 20°C (Jonez and Sumner 1954) in late May and continues through July. In the Colorado River, spawning occurs May through September (Arizona Game and Fish Department 1961). As with largemouth bass, sudden drops in temperature can cause spawning failure (Buck and Thoits 1970). Turbidity is detrimental to reproduction (Buck 1956). Data on other physio/chemical factors affecting reproduction is unavailable.

Embryo Development

Eggs have a longer viable life than sperm. Eggs 30 minutes old prior to fertilization still gave a 50 percent hatch, but sperm over 4 minutes old were incapable of fertilizing eggs (Childers 1967). Average functional life span was estimated at 1 minute for sperm, 67 minutes for eggs.

Best hatching success occurs at 27.3°C in 32 hours, incubation takes 71 hours at 22.6°C and 34 hours at 26.9°C (Childers 1967). Related hatching success was 56 percent at 22.6°C; 83 percent at 26.9°C and 90 percent at 27.3°C. Fry size at birth was also related to temperature and ranged from 3.26-3.72 mm at 23.5°C (Toetz 1966) to 4.98 mm at 26.9°C (Childers 1967). The 11-day TL m of fry was 13 percent seawater (Tebo and McCoy 1964) and there was no surviving spawn at salinities of 0.5 percent (Swingle 1949).

Fry and Juveniles

Fry become free swimming 10 days after fertilization at 6 mm in length (Werner 1969). Upon leaving the nest, the fry form a "ball" and travel freely within this school. These large schools eventually break up into small groups that disperse into cover. The male bluegill guards the fry until the schools break up (Jonez and Sumner 1954). Bluegill males are less aggressive protectors of fry than males of other centrarchid species (Carbine 1940). Unlike other sunfish, larval bluegills have a limnetic stage after initial swim-up. For a 6-7 week period, during which fry grow from 10-12 mm to 22-25 mm, the fry are schooling in the upper 3 m of the water column (Werner 1969).

Growth rate is rapid, ranging from 0.13 mm/day to 0.28 mm/day (Hall, Cooper and Werner 1970). Fry consume zooplankton, and the dawn and dusk movements of fry correspond to zooplankton movements (Werner 1969).

Survival of fry is influenced by several factors. Hydra in nests may kill many prior to the schooling period (Clady and Ulrichson 1968). Starvation mortality becomes heavy after 6.5-7 days post-hatching (Toetz 1966). If vegetative cover is not abundant, fry are easily preyed on by largemouth bass, adult bluegills and other predators. Fry are especially vulnerable up to 2.5 cm in length (Beland 1954). Since bluegill spawn later in the year than bass, young of the year bass are abundant in shallow areas to prey on bluegill fry (Weaver 1971; Jonez and Sumner 1954). Declining summer water levels, that force fry out of aquatic vegetation, also results in low survival (due to predation and natural causes) (Jonez and Sumner 1954). When bluegill fry are stocked alone, survival rates to the first fall were 75-100 percent (Smith and Swingle 1943). However, when stocked with bass fingerlings, survival fell to 76-85 percent (Beyerle and Williams 1972).

Juvenile bluegills growth rates range from 0.1 mm/day to 0.6 mm/day (Hall et al 1970; Krumholtz 1949; Lux 1960; Werner 1969). Average growth in Lake Mead was 10 cm at the end of the first year and 20 cm at the end of the second year (Jonez and Sumner 1954). Growth rates from Mead and Mohave are similar to those from other lakes and are considered good (Roden 1978).

Juveniles consume the same foods as adults. Aquatic insects, plankton, plants and fish are of varying importance in the diet. Chironomid larvae were the most important food in Imperial Reservoir during the spring, summer and fall. Zooplankton were important during the winter (Weaver 1971). Similar food habits were found in Lake Mead. Chironomid larvae, corixid adults and odonate nymphs were available and utilized extensively during the warm seasons while plankton and algae dominated the diet in the winter (Jonez and Sumner 1954). Insects comprised 56 percent, plankton 31 percent, plant 8 percent, and fish 5 percent of the diet in that study. Fish eggs are also consumed (Deacon et al 1972). Juvenile bluegill are more tolerant of environmental conditions than are adults. Maximum growth temperature is 30° C. Significant declines in growth rates occur at temperatures below 20°C or above 36°C (Lemke 1977). Preferred temperatures are 28-33°C (Beitinger 1974; Ferguson 1958; Neill and Hagnuson 1974). Juveniles are also very tolerant of low dissolved oxygen but cannot survive concentrations below 0.5 ppm-0.8 ppm (Douderoff and Shumway 1970). Growth is slower at pH's of 6.3-7.4 than at pH 7.0-7.8 (Stockinger and Hays 1960).

Adults

Age and Growth

Adult bluegill in healthy populations average 23-30 cm TL (Roden 1978).

Good growth is 2.5 cm/yr after the first year (when the fish reaches 5-7.5 cm) (Nevada Department of Fish and Game 1977A). A rapidly growing population reaches 12.7 cm in 2.8-3.5 years while a slow growing population will take 4-5 years to reach the same length (Eddy and Carlander 1940). Growth rates are directly related to population density (Carlander 1977). Due to the high fecundity of the species, bluegill tend to overpopulate and produce stunted populations. In a stunted population, the average length of a mature fish may be less than 15 cm (Walden 1964). These populations are dominated by age II and III fish, with few surviving beyong age V (Anderson 1973). When population densities drop, growth rates of the remaining fish increase sharply. Stunted bluegills grew to 22.9 cm in 7 months after lake renovation (Selbig 1970).

The oldest reported bluegill was an age XI fish (Schloemer 1939) but most live 1-4 years (Carlander 1977). Conflucting data exist on differences in growth rates between sexes. This implies great variability in growth from population to population (Emig 1966). The largest bluegill ever caught in Lake Mead was a 26.7 cm, .68 kg fish. Occasional catches of fish .45 kg or larger are made in both Mead and Mohave (Roden 1978).

Feeding

Adult bluegill are omnivorous. Aquatic insects, especially midge larvae, dominate the diet with zooplankton and plant material of secondary importance (Sarker 1977). Other foods utilized include small fish, fish eggs, snails, small crayfish and amphipods (Swingle 1949b, Harlan and Speaker 1956), as well as water mites, ostracods and odonate nymphs (Roden 1978). In cold months plankton and algae are more heavily utilized

(Jonez and Sumner 1954). Bluegill are primarily daylight feeders. The peak of stomach fullness occurs just before dark (Sarker 1977). There is some night feeding but generally less than the daytime component.

At 10^{o}C, 14-19 g bluegills ate 0.7-1.9 percent of their weight per day, and at 20^{o}C 4.7-6.2 percent (Hathaway 1927). Daily rations have been recorded from 1-2 percent of body weight per day (Seaburg and Moyle 1964) to 1.16 to 3.59 percent (Gerking 1955). Daily intake per weight of fish was lower for large fish than small fish (Seaburg and Moyle 1964) and positively correlated with increasing temperature. In Missouri, bluegills ate 336 percent of their body weight during the growing season and only 13 percent over the rest of the year (Anderson 1958).

Movement

From late fall to early spring bluegill remain in deep, often 15 meters or more, water. As water temperatures rise in the spring, the fish move inshore to shallow water (Jonez and Sumner 1954) and remain there, in less than .9 m of water, during the summer. Bluegill do not travel great distances. Of recovered fish from Three Sister Lake, Michigan, 60 percent came from within 27.5 m of the release site (Ball 1947). In Lakes Mead and Mohave, tagging studies from the early 1950's revealed that long distance movements do exist. One Mead bluegill was recovered 8.1 km from the release site, while a Mohave fish travelled nearly 13 km uplake (Jonez and Sumner 1954). Bluegill also have daily movements between the littoral and limnetic zones that may be related to feeding (Baumann and Kitchell 1974). Bluegill spend the day in limnetic areas feeding on zooplankton and move to the littoral in the evening to feed on benthos and aufwuchs. Large (over 12.9 cm TL) fish tend to spend more time in the littoral during the day since benthos is more important in their diet (Beitinger 1974).

Physical Factors

Bluegill prefer low velocity areas, deep pools and backwaters and avoid riffles (Catelin and Reynolds 1975; Moyle and Nichols 1973). There is no preference for substrate (Clark and Keenleyside 1967; Flemer and Woolcott 1966). On the Colorado River they are abundant in the mainstream reservoirs, in backwaters in Topock Marsh and Imperial Reservoir (Jonez and Sumner 1954; Beland 1953; Beland 1954; Marshall 1971), clear, still backwaters (Gumtow 1967) and pools in the main channel (Guntow 1965). Abundant aquatic vegetation is utilized as cover by small fish (Beland 1954).

Bluegill tolerate a wide extreme of temperatures although they prefer the range 15.6°C to 26.7°C (Rounsefell and Everhart 1953). Lower lethal limit is 2.5°C and the upper is 33.8°C (Bennett 1962). Bluegill can survive for short periods at 35°C (Moss and Scott 1961). At 21.3-21.8°C, fingerlings died in 20 hours at .8 ppm O_2 and stopped eating at 1 ppm (Petit 1973). Bluegill will avoid O_2 concentrations near 1.5 ppm (Whitmore et al 1960). Minimum survival concentrations vary with temperature. At 2.5-4.0°C, ventilation rates increased as oxygen was reduced from 4 mg/l to 1 mg/l, held steady at 0.5 mg/l and fish died at 0.26 mg/l (Petrosky and Magnuson 1973). Bluegill do not surface in low oxygen conditions so are more prone to winter kill (Carlander 1977). The rate of decline of oxygen concentrations will also influence the lethal oxygen concentration. At slow lowering at 25°C, death occurred at 0.70 mg/l. At fast lowering at 35°C, death occurred at 1.23 mg/l (Moss and Scott 1961).

Bluegill can tolerate pH's from 4.0 to 10.35±.15 (Trama 1954). They have been reported to withstand transfers from pH 8.2-8.7 to pH 4.4 to 6.4, but at dissolved oxygen concentrations of 5 ppm, there were some mortalities when fish were transferred from pH 7.9 to pH 9.5 (Wiebe 1931). At higher oxygen concentrations, pH changes have less impact.

Bluegill prefer non-turbid water (Buck 1956) and have been found in salinities of 2 ppt (Carver 1967), 4.5 ppt (Chiszar, Moody and Windell 1972), and 5.6 ppt (Kilby 1955). They are recommended for stocking in slightly alkaline lakes with less than 900 ppm total alkalinity, 250 ppm carbonate alkalinity, and 200 ppm K^+ Na (Bailey, Winn and Smith 1954).

III. Interactions

Although bluegill are considered a sport fish, in many areas their primary function is to provide forage for the larger, more desirable predator species. Bluegill have been stocked with largemouth bass in warmwater lakes all over North America.

Bluegill are satisfactory forage fish for bass for several reasons. They spawn later, providing young of year bass with an abundant food source at the time they begin to turn piscivorous (Weaver 1971; Jonez and Sumner 1954).

Fry survival is often quite low; bluegill are very vulnerable to predation up to 2.5 cm in length (Beland 1954) but remain vulnerable beyond this size. An important factor in the vulnerability is one ratio of body length to depth. Bass can only swallow a fish as deep as its mouth gape, so bluegill, a deep bodied species, may not be available to certain sizes of bass (Lawrence 1957; Moyle and Holzhauser 1978). Known predators include largemouth bass, walleye, rainbow trout and adult bluegills.

In lakes and reservoirs with overabundant cover, survival rates of young bluegill may be higher than usual. This, in combination with other factors leads to overpopulation and stunting. In a lake with a stunted bluegill population, predator fish are rare. It has been shown that high densities of sunfish will prevent bass from nesting (Smith 1976) and adult bluegills will prey on bass fry (Beland 1954; Jonez and Sumner 1954).

Competition for available food resources by different fish species will also have an impact on bluegill populations. Competition with carp for bottom fauna may have surpressed bluegill growth in California (Wohlschlag and Woodhull 1953). Decrease of condition factors in bluegill was noted after carp were introduced in a Pennsylvania lake (Cooper, Wagner and Kranz 1971). Threadfin shad (<u>Dorosoma petenense</u>) may compete with young bluegills for zooplankton.

IV. Fishery

In other areas of the country, bluegill provide good fishing. They are considered good eating and provide excellent sport on light tackle. In the Colorado River, bluegill provide limited fishing because of their small size. In the 1950's, they made up only 2 percent of the sport catch in Lakes Mead and Mohave with average sizes ranging from 5.7" in 1952 to 7.2" in 1954 (Jonez and Sumner 1954). In more recent years the catch has increased, with a high of 9.3 percent in 1971 for Lake Mohave and 19.2 percent in 1970 in Lake Mead (Roden 1978). Although bluegill are caught in the entire length of the river, they are important only in a few areas, especially in the Imperial Division.

BONYTAIL CHUB

I. Introduction

Gila elegans, the bonytail chub, is one of the four "big river" fish native to the Colorado River drainage. Highly streamlined with a broad, concave skull and the pencil-thin caudal peduncle that gave it its name, bonytails were once relatively abundant throughout the river system (Cope and Yarrow 1875; Jordan 1891; Gilbert and Scofield 1898; Chamberlain 1904). Between 1926 and the 1950's, they have been nearly eliminated from the lower basin and their numbers in the upper basin have declined as well (Joseph and Sinning 1977). A small, relict population in Lake Mohave is all that remains of the bonytail in the lower basin, the last bonytail seen in Lake Mead was in 1967 (Roden 1978). There has been no successful reproduction documented in the lower basin for many years.

II. Life History

Little is known of the reproductive habits of the bonytail. In Lake Mohave in 1954, Jonez and Sumner (1954) observed 500 bonytails spawning on a gravel bar near El Dorado Fishing Camp. Fish spawning in Lake Mohave were 28 to 35 cm long with an average length of 30 cm. A 30 cm female had 10,000 ripe eggs, pasty white in color and 0.78 mm in diameter. Each female was accompanied by 3-5 males. The adhesive eggs were broadcast on the gravel and received no parental care. Water depth was as much as 9 meters. Spawning bonytails had bright reddish-gold sides and bellies.

Spawning occurs on receding water levels at 18°C (Vanicek and Kramer 1969; Holden 1973). Bonytails spawned in May in Lake Mohave (Jonez and Sumner 1954). Large schools of carp were present on the Mohave spawning area, it is doubtful any eggs survived. There is no specific information on the early development of the bonytail. It is assumed that fry remain in quiet water areas to feed and grow and enter deeper water later (Minckley 1973). It is believed that growth is slow for the first 3 years, then becomes faster (Vanicek 1967).

Adult bonytails may live as long as 7 years (Vanicek and Kramer 1969) and reach 47 cm in length (Everhart and Seaman 1971). In Lake Mohave, 28 cm FL fish averaged 260 gms; 30 cm FL fish 300 gms, 33.0 cm FL fish 350 gms and 35.6 cm FL fish 425 gms (Jonez and Sumner 1954).

Bonytails feed mainly on terrestrial and aquatic insects, plant debris and filamentous algae (Vanicek and Kramer 1969). Jonez and Sumner (1954) reported plankton, aquatic insects (especially midge larvae), algae and organic debris made up the bonytail diet. There are no known seasonal or geographic differences in diet (Vanicek and Kramer 1969).

Bonytails were only found in large, turbid rivers, especially in the swift water canyons. It was collected primarily from eddies adjacent to swift water (Vanicek 1967; Holden 1973). Nothing more is known of their habitat requirements.

III. Interactions

Prior to the introduction of exotic fish species into the Colorado River, the Colorado squawfish was the primary predator on adults, and probably young bonytails. Roundtail chubs probably preyed on the young. The number of potential predators on young, and possibly adult bonytails now includes largemouth bass, channel catfish, green sunfish, red shiner and redside shiner. The later two may be a serious threat to larval and juvenile bonytails as they share the same habitat (Joseph and Sinning 1977).

IV. Fishery

Bonytails were sought as food by Indians and settlers. When present, they are easily taken on hook and line (LaRivers 1962; Sigler and Miller 1963).

Bonytails are listed as endangered under the Endangered Species Act of 1973 (as amended) and are on the state lists of Arizona, California, and Nevada.

HUMPBACK CHUB

I. Introduction

The last of the native, big river fish to be discovered, the humpback chub, Gila cypha, was not described until 1946 (Miller 1946). Presently, populations are found in the Grand Canyon, and areas of the Green River, Yampa River and Colorado River in Utah and Colorado. The species may never have been very abundant (Joseph and Sinning 1977).

II. Life History

Very little specific information exists on the spawning of the humpback chub. Extrapolations from the closely related Gila robusta, the roundtail chub, and Gila elegans, the bonytail chub, imply that reproductive requirements are quite similar for the three species (Holden 1977b; Joseph and Sinning 1977; USDI FWS 1979A).

Adult humpback have spawning coloration similar to the bonytail. In males, the belly, and bases of the anal and pectoral fins are orange. The cheek below the eye is pinkish orange and the iris is yellow. The female is light orange on the belly and the base of the anal fin. The pectoral fin base is cream colored. Both sexes have tubercles, but those of the male are more extensive and larger. Male tubercles extend over the head, dorsally to the nuchal hump with a few on the underside of the head. Well developed tuberculate ridges are present on the breast and along the pectoral and pelvic fin rays. Females have tuberculate ridges on the breast and small tubercles on the pectoral fin rays (Suttkus and Clemmer 1977).

Mature ova from a preserved 30.5 cm fish measured 1.6-2.2 mm in diameter and were yellowish in color. Immature ova from the same fish were between 0.9-1.3 mm in diameter and pale in color. (Suttkis and Clemmer 1977).

Humpbacks probably spawn at or near 18^{o}C (Joseph and Sinning 1977; USDI FWS 1979A). They may spawn near pools and with much splashing of water, as was observed by the Kolb brothers at the mouth of the Little Colorado River in 1914 (Suttkus and Clemmer 1977). In Desolation Canyon (Green River, Utah) spawning occurs in May or June (USDI FWS 1979A). In the Grand Canyon spawning times are later, June and July (Suttkus and Clemmer 1977).

Young of the year humpbacks reach 30-70 mm in September in Desolation Canyon (Holden 1977) and 24 mm in the Grand Canyon (Suttkus and Clemmer 1977). Juveniles age (1 and 2) from Desolation Canyon were 70-150 mm. The characteristic nuchal hump does not begin to develop until about 100 mm in length (Suttkus and Clemmer 1977). Young of year and juvenile chubs preferred habitats with little current, silt substrate and depths of 0.3-1.0 m (Holden 1977). Juveniles may also be found in faster water areas (Joseph and Sinning 1977). Adult chubs may reach 38-50 cm but more usually they seldom exceed 33 cm (Roden 1978). The type specimen measured 305 mm SL (Miller 1946).

The subterminal mouth implies that humpbacks are bottom feeders (Miller 1946), but field observations show them feeding on the surface in runs and eddies (Joseph and Sinning 1977). Humpbacks below Glen Canyon Dam fed on zooplankton coming from Lake Powell (Minckley 1973).

Adult humpbacks are collected in, or adjacent to, deep swift water (Holden and Stalnaker 1975) in canyon areas of large rivers. Microhabitat studies (Holden 1977) show that shallow, slower areas in the canyons are more heavily utilized. Adults did utilize a wide variety of areas, usually with a sand substrate, with little preference for certain depths or velocities.

III. Interactions

Few predators find the specialized habitat of the humpback chub to their liking. Young humpbacks, in the shallow, slower areas, may be more vulnerable to predation by both introduced and native fish species (Miller 1961; Holden, et al, 1974).

There is evidence of hybridization between the humpback and roundtail chubs (Holden, et al, 1974). Some authors believe that modification of the river may have speeded up a possible natural hybridization rate (Minckley 1973; Johnson 1976). In any case, there is a gradual "swamping" of pure humpback genetic stocks (Holden and Stalnaker 1970, 1975; Holden 1977).

IV. Fishery

Humpback chubs have no sport fishing or commercial value. Their value comes from their status as a unique endemic species from the Colorado River. They are listed as Endangered under the Endangered Species Act of 1973 (as amended) and are on the state list of Arizona and Nevada.

RAZORBACK SUCKER

I. Introduction

Before man's modification of the Colorado River, the razorback sucker, *Xyrauchen texanus*, was one of the most common fish in the river (Dill 1944). In the late 1800's their range encompassed the mainstem Colorado River and major tributaries from Wyoming to the delta in Mexico (Abbott 1961; Lockington 1880; Jordan 1891; Evermann and Rutter 1895; Gilbert and Scofield 1898; Ellis 1914).

Since the early 1900's razorback populations have declined. Low river flow, construction of impoundments and introduction of exotic species served to change the physical, chemical and biological regime of the Colorado (Dill 1944; Miller 1961; Minckley 1973; Holden and Stalnaker 1975). Presently, the species is found in Lake Mohave, Lake Havasu, and the lower Colorado River especially in Senator Wash Reservoir, Parker Division and the Colorado River Indian Reservation (Minckley 1973; Gustafson 1976; USDI FWS 1979C).

II. Life History

The age or size at maturity in razorback suckers is unknown. In Lake Mohave, the smallest fish captured, a 30.5 cm male and a 31.2 cm female, were both mature and were probably over 7 years old (Gustafson and Minckley 1975A).

Adults are easily sexed especially during the breeding season. Differential coloration and tuberculation are extremely obvious at that time. Males are dark olivaceous to black dorsally, the ventral area bright orange. There is a dark pink to reddish lateral stripe. Females retain the usual drab coloration, olivaceous dorsally and an off-white belly (Douglas 1952, Minckley 1973). Males have large conical tubercles on the anal fin and lower lobe of the caudal fin. The pectoral and pelvic fins and lateral and ventral areas on the caudal peduncle have smaller conical tubercles. Females may have a few small tubercles on the anal fin, lower lobe of caudal fin and caudal peduncle but none on the pelvic or pectoral fins (Gustafson and Minckley 1975A).

Fecundity seems high and increases with length and weight of the fish. Average fecundity is 1906 eggs per cm standard length (Gustafson and Minckley 1975A) and ranged from 102,250 eggs in a 57 cm fish to 74,600 in a 39.1 cm fish.

Spawning behavior is similar to that in other suckers. Jonez and Sumner (1954), Douglas (1952), and Gustafson and Minckley (1976) describe spawning groups of from 2-10 males with one ripe female moving along the shallows. The female is in the center of the group with the males pressed in close on all sides. Actual spawning consists of sudden, sidewise undulations that last from 30 seconds to 1½ minutes. Spawning takes place near the substrate. The group then moves away in loose formation. Cessation of spawning is initiated by the female and she may spawn several times in an hour with the same or different males in attendance.

Spawning begins in March and lasts until July with a peak in March and April. Temperatures of 12.2-18.3^{o}C (Jonez and Sumner 1954; McDonald and Dotson 1960) were reported in Lake Mead and 17-22^{o}C (Douglas 1957) in Lake Mohave and Lake Havasu (Carlander 1969). Spawning in the Yampa River, Colorado, occurred at 6-10^{o}C and in the Colorado River and a gravel pit near Grand Junction, Colorado at 12^{o}C and 17^{o}C respectively (Joseph and Sinning 1977).

Spawning occurs at 0.3-6.0 m over silt, sand, gravel or rocks (Roden 1978) or riffles (Joseph and Sinning 1977) with cobble sized rocks. Current may be important, shorelines with wave action are often utilized and in the Yampa River, spawning sites at the head of islands had current velocities of 3-5 feet per second (Joseph and Sinning 1977).

Spawning has been observed in many areas of Lake Mead and Lake Mohave. In Mohave, areas around Cottonwood Cove, El Dorado Landing and below Hoover Dam on gravel bars (Jonez and Sumner 1954; Gustafson and Minckley 1975B; Roden 1978) have been utilized by spawning razorbacks.

Razorback eggs are milky-white, adhesive and average 15 mm in diameter (Gustafson and Minckley 1975A). Once broadcast, they settle to the substrate, receiving no parental care. Egg survival is very low, carp follow spawning suckers and feed on the eggs (Jonez and Sumner 1954).

The eggs will hatch in 5-6 days at 14.4^{o}C. Length at hatching is 5-7 mm and fry have little, if any, pigment until 6 days after hatching. At that time, the eyes are pigmented and the fry swim up and begin to feed. First foods are zooplankton and simuliid larvae (in raceways at Willow Beach NFH) and growth is rapid. Fry reached 35 mm TL less than 1 month after the eggs were spawned. From this time, a considerable variation in size occurred. Fingerlings on June 30 averaged 60-70 mm, with some over 76 mm (Toney 1974). Presently, these fish range in size from 10.2 cm to 35.6 cm TL. At 2 years of age they ranged from 70 to 200 mm with a mean of 170 mm (Gustafson and Minckley 1975A).

Fry are preyed on by centrarchids as well as carp (Jonez and Sumner 1954), so it is doubtful that many survive. In recent years there have been few reported captures of young razorbacks. In 1980 (January and March) two young razorbacks were taken in a canal on the Colorado River Indian Reservation. The first fish was 32.7 cm and weighed 340 gms, the second was 37.1 cm and weighed 56.7 gms (Michael Donahoo, Fishery Assistance, Parker, USFWS, pers. comm).

Gustafson and Minckley (1975A) describe the embryonic and larval development of the razorback in great detail. The characteristic nuchal keel is not developed until the fish are approximately 90 mm (227 days old), even at this time it is scarcely visible and will develop more fully with increasing size.

Razorbacks will hybridize with other suckers, including the flannelmouth Catostomus latipinnis (Hubbs and Miller 1953; Gustafson and Minckley 1975B) and C. insignis (Gustafson and Minckley 1975B). The relative abundance of these hybrids may be increasing (Joseph and Sinning 1977).

Hybrids with the exotic sucker C. commersoni form six percent of the Mohave population (Gustafson and Minckley 1975B).

Adult razorbacks can reach 1 meter in length and weigh as much as 7.3 kg (Hubbs and Miller 1953; Minckley and Deacon 1968; Minckley 1973). Females usually grow larger (Sigler and Miller 1963; Gustafson and Minckley 1975) and the largest specimens are from the southern areas of the range. Razorbacks are long lived fish as evidenced by their persistance in reservoirs for several years after impoundment with no successful reproduction. Average size of razorbacks in Lake Mohave is 49 cm FL (Roden 1978).

Adult razorbacks can feed on the bottom or in open water. They consume algae, decaying organic matter, insect larvae and plankton. Some changes in food habits may occur seasonally (Jonez and Sumner 1954; Hubbs and Miller 1953). Razorbacks also feed on zooplankton near the surface; swimming in a slightly heads-up attitude with their mouths open (Roden 1978).

Razorbacks prefer areas of high primary productivity and detritus (Miller 1979). They are found in areas of swift current (Sigler and Miller 1963) or in quiet backwaters or eddies (Minckley 1973). Young fish are found in pools and eddies near shore (Joseph and Sinning 1977). The unique shape of the nuchal keel may be an advantage in swift rivers to maintain stability (LaRivers 1962). Adult razorbacks seem to do well in reservoirs and are distributed throughout the water from 1-15 m deep (Minckley 1973) and come inshore or up tributaries to spawn.

III. Interactions

Razorback suckers are not predators, thus they do not compete for forage with game fish. They are, however, themselves preyed on while young. Carp and centrarchids are known predators and it is likely that the Colorado River squawfish, *Ptychocheilus lucius*, was a common predator in the past.

There may be some competition for spawning sites, since razorbacks spawn in the same areas as centrarchids, but since razorbacks do not build or defend nests, this interaction is probably minimal. Razorback fry consume similar foods as the young of centrarchids.

IV. Fishery

When razorbacks were abundant, they were a sought after commercial food fish. Native Indians had earlier made extensive use of them (Hubbs and Miller 1953; Sigler and Miller 1963; LaRivers 1962).

Today they are rare and, even though locally common, are in danger of disappearing. They are protected under Arizona, California, and Nevada State law and were proposed as "Threatened" to the Endangered Species list maintained by the Federal government.

IV. Fish Diseases and Parasites

The occurrence of fish diseases within the study area has not been widely studied or reported. Various state and federal field offices along the river and some of the universities in Arizona, California and Nevada have done some work on diseases of fish from the Colorado River. The most heavily surveyed area is the Willow Beach National Fish Hatchery on Lake Mohave. The bulk of the literature on diseases deals with those organisms isolated and identified at the hatchery (Buckner 1972; Rosenlund 1975, 1977; Nevada 1977; Roden 1978; Landers and Mpoame 1979; Majors 1979, 1980). The remaining references cite diseases and pathogens found in Lake Mohave or the lower section of the river (Kimsey 1956; Troth 1963; Miller 1965; Weaver 1971; Donahoo, Pers. Comm). The diseases that have been identified and reported are listed in Table 9 and locations of occurrence shown on Figure 12.

The epizootic conditions necessary to cause major mortalities in fish have only been reported in the hatchery at Willow Beach. Infectious Pancreatic Necrosis (IPN) was known to be present in fish from Willow Beach National Fish Hatchery in 1970. A study of Lake Mohave fish near the hatchery began in 1974 and concluded in 1976. The results indicated one-fourth of the fish outside of the hatchery were carriers for the IPN virus (Rosenlund 1977). Since that time intensive disinfection and testing programs have been carried out at the hatchery. Test results from fish in the hatchery and Lake Mohave showed them to be negative for the virus (Rosenlund 1977; Majors 1980).

Bacterial gill disease is known to occur at the hatchery but is kept in check using established fish cultural techniques. There is a possibility

Table 9. List of identified and reported bacterial and viral diseases, parasites and fungal infections found associated with fish in the Colorado River system between Hoover Dam and the International Boundary.

Organism	Fish Species	River Location
BACTERIA		
Yersinia ruckeri	RBT	3A
Flexibacter sp.	RBT, RBS, CSQ, BTC, TFS	3A
Aeromonas hydrohpila	RBT, RBS, CSQ, BTC, TFS	3A
Pseudomonas fluorescens	RBT, CSQ	3A
Flavobacteria sp.	RBT	3A
Vibrio sp.	RBT	3A
VIRUS		
Infectious Pancreatic Necrosis (IPNV)	RBT	3A
PARASITES		
Lernaea sp.	RBT, BTC, BLG, BCR, LMB	3A, 3B, 3C, 4B, 4C
Lernaea crassii		4C
Ichthyopthirius multifilis	RBS	3A
Costia sp.		3A
Trichodina sp.		3A
Scyphidia sp.	CCF	4C
Pliestophora salmonae	RBT	3A
Epistylis sp.		3A
Myxobolus sp.	RBS	3A
Myxosoma sp.	RBS, CSQ	3A
Gyrodactylus sp.	RBT	3A

Organism	Fish Species	River Location
Monogenetic trematode (suborder Polyoptocotylea)	RBS	3A
Sanguinicola sp.	RBT	3A
Posthodiplostomum minimum		4C
Posthodiplostomum minimum centrarchi	BLG, WRM, LMB, GSF	4C
Clinostomum marginatum	LMB	5A, 5B
Contracaecum sp.	LMB	3B, 3C, 4B
Contracaecum brachyurum	LMB, BLG, WRM, RES	3A
Contracaecum multipapillatum	RBT	
Contracaecum spiculigerum	BLG, WRM, RES, LMB	4C
Proteocephalus sp.		4C
Proteocephalus ambloplitis	LMB, BCR, BLG	3A, 4C
Ophiotaenia fragilus	CSQ	3A
FUNGUS		
Saprolignea sp.	RBS, centrarchid nests	3A
LEECHES		
Illinobdella sp.		3A

Key to fish species abbreviations.

BCR - black crappie
BLG - bluegill
BTC - bonytail chub
CCS - channel catfish
CSQ - Colorado River Squawfish
GSF - green sunfish
LMB - largemouth bass
RES - redear sunfish
RBS - razorback sucker
RBT - rainbow trout
TFS - threadfin shad
WRM - warmouth

Location map for fish diseases and parasites.

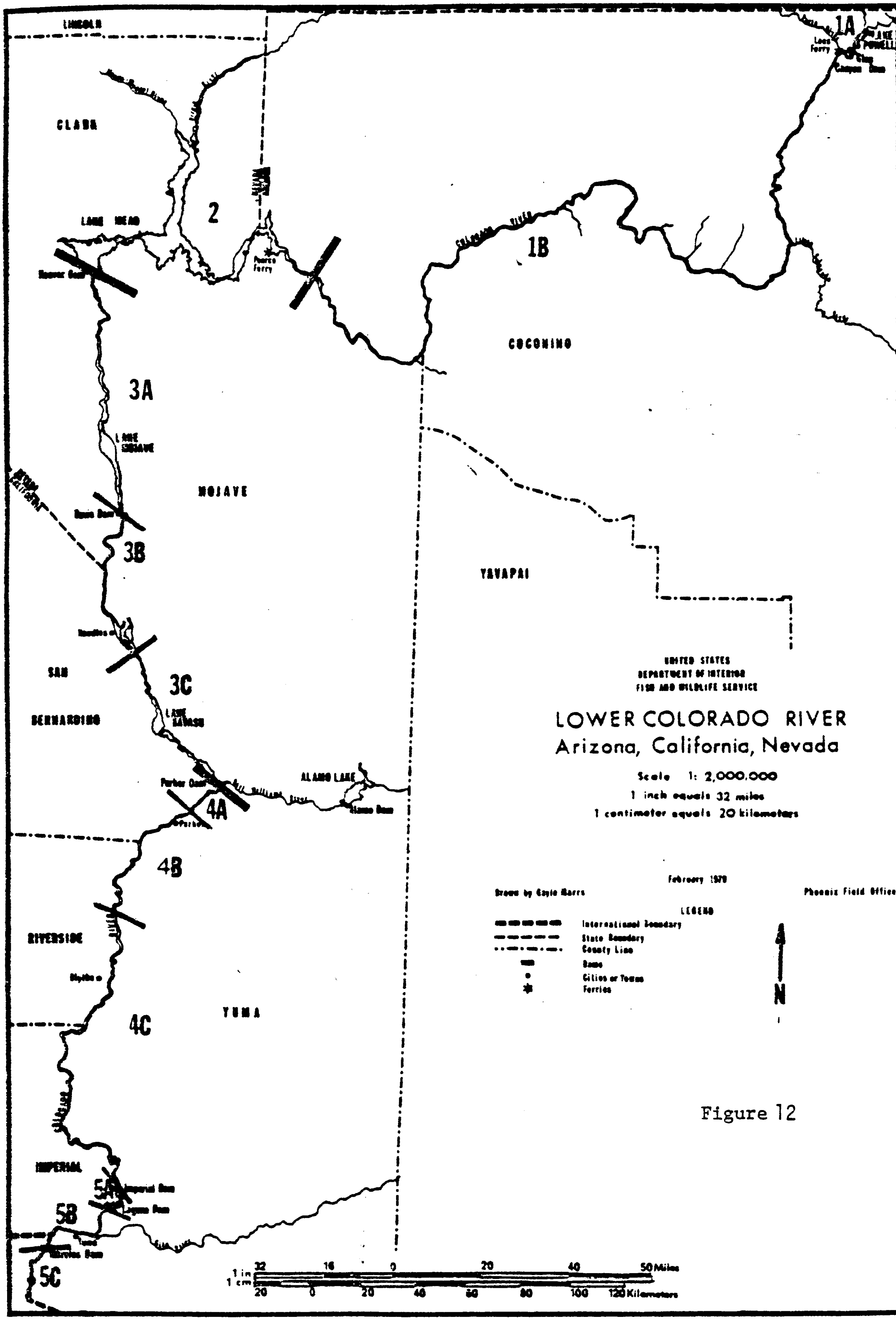


Figure 12

that other disease problems exist throughout the study area but as of this writing, no known reports of major outbreaks have been found.

In areas away from the hatchery environment there are several diseases known to exist but none of them are causing any problems. There is a consistent occurrence of a nemotode Contracaecum sp. being found in fish from Topock March, Gene Reservoir, Parker II and the Yuma Division along the river (Donahoo, Pers. comm. 1980).

State and Federal regulations and policies governing the handling of fish diseases now exist. The Federal government, the Colorado River Wildlife Council and the States of Arizona, California, and Nevada have jointly and individually provided guidelines and policies for controlling the spread of serious fish diseases.

The U. S. Fish and Wildlife Service states in its "Fish Health Policy" that its general mission is to:

1) Provide leadership, professional competence and training, in cooperation with international agencies, foreign governments, states, and the private sector, to organize and carry out programs to improve fish health.

2) Develop programs in cooperation with other Federal and State agencies and the private sector to solve fish health problems and control the spread of serious disease agents.

3) Increase the efficiency of fishery resource programs by minimizing the impact of disease and by producing healthy fish to meet the objectives of fishery management programs, research, and cooperating agencies.

4) Encourage and conduct research and development studies of the epizootiology of fish diseases, improved disease detection and diagnostic techniques, additional methods of effective therapy and disease eradication procedures, and improvements in the disease resistance of cultured fish species.

5) Evaluate the threat each disease poses to the resource and determine which specific diseases should be listed as certifiable (Table 10).

At the present time the guidelines for implementing this policy are in draft form which says that the Fish and Wildlife Service will take the following action with regards to the policy:

1) "Conduct research to determine interrrelationships of the environment, pathogen, and hosts for the betterment of fish health.

2) Continue the fish hatchery disease monitoring and reporting program at all Service fish hatcheries and fishery research facilities.

3) Provide training for fishery biologists in fish health to assure sound management of hatchery and feral populations of fish.

4) Insure that the national broodstock and fish stocking programs comply with the fish health policy.

5) Develop and execute agreements with cooperators to identify areas of responsibility and assure continued responsiveness to resource needs.

6) Execute the fish health policy to comply with the Endangered Species Act of 1973 and all its amendments.

Table 10. U.S. Fish and Wildlife Service Certifiable Diseases.

Diseases
Furunculosis
Bacterial kidney disease
Enteric redmouth
Whirling disease
Viral hemorrhagic septicemia
Infectious pancreatic necrosis
Infectious hematopoietic necrosis
Ceratomyxa shasta
Herpescirus salmonis
Channel catfish virus

7) Maintain a Technical Advisory Group (TAG) to evaluate current knowledge of fish diseases, determine areas requiring research and develop and periodically update information for the control or eradication of disease."

The objectives of these guidelines and policies are to produce healthy fish in the hatchery and maintain the survival of fish in the wild. (Anderson, Pers. Comm. 1980).

In 1973 the Colorado River Wildlife Council (CWRC) comprised of the seven western states within the Colorado River drainage system adopted a program to monitor fish diseases within the system. Each state and the Federal government have appointed inspectors representing their agencies to inspect the state, private, or federal hatcheries within their state or region. The inspections are made on any facility which stocks fish into the Colorado River drainage. Inspection schedules are set up for the individual stations by the biologist and then are reported to the Chairman of the Fish Disease Subcommittee who in turn contacts an appropriate Certifying Team Member who will complete the inspections and report the results back to the Chairman. The policy adopted by the council states the following:

1) "Before any station may stock game fish into the Colorado River drainage system or conduct fish cultural activities on the Colorado River system it shall be certified by a member or members of the Certifying Team as being free of the fish diseases or pathogens inducing the diseases listed in this policy (Table 11).

Table 11. List of diseases and pathogens which the Colorado River Wildlife Council indicates fish should be free from before being stocked into the Colorado River Drainage (Adopted in 1973, amended in 1974, 1976, 1978, and 1980).

1. I.H.N. Virus - Infectious Hematopoietic Necrosis of Salmonids
2. WHSE Virus - Viral Hemorrhagic Septicemis of Salmonids
3. C.C. Virus - Channel Catfish Virus Disease (Viral disease syndrome of Ictalurids)
4. *Myxosoma cerebralis* - Whirling Disease of Salmonids
5. K.D. - Corynebacterial Kidney Disease of Salmonids
6. *Ceratomyxa shasta* - Ceratomyxa Disease of Salmonids
7. *Branchiomyces* sp - European Gill Rot of *Morone saxatilis*
8. *Sanguinicola* sp - (Cardicola) - Blood Fluke of Salmonids
9. I.P.N. - Infectious Pancreatic Necrosis of Salmonids

2) There shall be no plantings of game fish into the Colorado River system from any station exhibiting significant fish losses and showing clinical symptoms of any disease, nor shall any station draining into the Colorado River system which exhibits such diseases be allowed to operate until properly certified.

3) All game fish planted by federal, state and private fish cultural facilities into the Colorado River drainage system shall be free of the disease or pathogens inducing the diseases listed in the policy. Fish cultural facilities with a history of incidence of any of these diseases shall not plant fish into the Colorado River drainage system until inspected by a member or members of the Certifying Team and found to be free of the listed diseases or pathogens inducing those diseases.

4) Any certification of clearance for planting game fish into or conducting fish cultural activities on the Colorado River drainage system is immediately null and void upon confirmation that any of the listed diseases are established in the certified hatchery. Further game fish plantings may be made into the Colorado River Drainage system only after recertification and after the Colorado River Wildlife Council recommends that planting may be resumed.

Each of the States along the lower Colorado River support the Council policy and each maintains its own state regulations governing fish health as well. Arizona complies with the general direction of the Council and stocks fish according to those directions (Silvey, Pers. Comm. 1980). California requires fish entering the state to be clean and in good health (Wolf, Pers. Comm. 1980). Nevada requires that any one operating any type of fish cultural installation obtain a letter of certification stating the facility is free of deleterious fish diseases (Roden 1978).

V. AQUATIC PLANTS

Aquatic vegetation is an important component of the biota of the Colorado River. Both emergent and submerged aquatics provide extensive benefits to the other biota.

Emergent plants, such as cattails, rushes, and giant reed stabilize the substrate with their rhizomes and entrap fine particulate material (Minckley 1979; Carothers and Minckley 1980). This entrapment not only provides more rooting space for the plant, but also a silty, sandy habitat for burrowing, benthic invertebrates such as chironomid larvae, aquatic oligochaetes (especially tubificids), some caddisfly larvae and other insects (Minckley 1978, Arizona Game and Fish Dept. 1961). Beds of submerged aquatics will provide the same benefits.

In addition to enhancing populations of benthic invertebrates, aquatic plants stimulate the production of other forage organisms. Submerged stems, rhizomes, and branches support an abundant periphyton population which is grazed by larger invertebrates or directly consumed by fish. The invertebrate populations sustain other fish species. Dragonflies damselflies, caddisflies, hemipterans, freshwater shrimp (Palaemonetes paludosus), snails and crayfish are some of the invertebrate groups that regularly inhabit beds of aquatic plants (St. Amant and Hulquist 1969; Marshall 1971; Saiki and Tash 1979). Dead plant material provides nutrients to encourage phytoplankton growth and detritus consumed directly by detritivorous invertebrates and fish.

In addition to their role in food production, aquatic plants provide cover for a myriad of creatures. Young of the year fish rely heavily on adequate cover to escape predators. Beds of aquatic plants provide excellent cover and the success or failure of a centrarchid year class, and consequently the success of the fisherman, can be directly related to the amount of available aquatic or flooded terrestrial vegetative cover (Beland 1954; Nevada Game and Fish Department 1967, 1968; USDI-Bur. Reclam. 1972, 1973; Weaver 1971; Shirley and Andrews 1977; Carothers and Minckley 1980). Roden (1978) summarized the importance of major plant groups to the fishery. Cattails, giant reed, Potamogetonaceae, *Najas spp*., Leguminosea, and *Tamarix spp*., were listed as being important as cover.

The presence or absence of aquatic emergent or submergent plants is dependent upon the physical characteristics of the water body. In the case of the Colorado River, flow rates and water levels are key factors. The main channel of the Colorado River supports very few higher aquatic or emergent plants. In the Grand Canyon reach (Region 1B), only *Zannichellia palustris* and the alga *Cladophora spp*., are found in the mainstem (Carothers and Minckley 1980). The flowing river segments below Davis Dam (Regions 3, 4, 5) have a more diverse flora, with *Potamogeton pectinatus*, *Myriophyllum spicatum exalbescens*, *M. brasiliense*, and *Chara spp*. in the main channel and *Ceratophyllum demersum*, *Najas marina*, *N. guadalupensis*, *Potamogeton foliosus* and *Zannichellia palustris* in the slower, shallower edge areas (Minckley 1979). Areas of moderate or dense stands of aquatic macrophytes were restricted to areas in the Mohave Valley, Havasu, and Parker Divisions, with the Imperial and Limitrophe Divisions being sparsely populated with plants (Minckley 1979).

Backwaters in the lower river and flowing tributaries in the Grand Canyon contained more and different species of plants. Spiny naiad (Najas marina) often choked backwaters in the summer. Flowing drains and canals also harbor substantial aquatic plant populations.

Emergent plants are more common in the backwaters, shallow side eddies of the main channel, and mouths of tributary streams. Extensive marshes are found in Topock Marsh, Bill Williams arm of Lake Havasu and the Imperial Reservoir. Bands of cattails, rushes, and giant reeds line some river banks in both the upper and lower river. These emergent populations were made possible by the regulation of water flow by dams, resulting in elimination of bank scouring floods (Carothers and Minckley 1980).

In the major reservoirs, beds of emergent and submergent plants are found in the shallow coves. Due to the severe water level fluctuations these reservoirs undergo, there may be a scarcity of plants, especially emergents. The clear water in the reservoirs permit submergent plants to grow at depths below the fluctuation zone, but extensive beds are often lacking in the coves that are nursery areas for game fish. In good water years, by late summer extensive plant beds have developed and in conjunction with flooded terrestrial vegetation, provide excellent cover for small fish (Nevada Game and Fish 1968; Shirley and Andrews 1977; Padilla 1980).

VI. AQUATIC INVERTEBRATES

Zooplankton and aquatic macroinvertebrates provide the forage base for most of the fish species present in the Colorado River. Even the large, piscivorous predators depend both directly and indirectly on the invertebrate food base since it forms their first food source, and the food for the forage fish these predators depend on. In some cases, as with adult largemouth bass and crayfish, the invertebrate is a preferred food.

Where necessary, invertebrate species have been introduced into the Colorado River to provide a forage base for a developing fishery. Some introductions, as with crayfish in the 1930's and 1940's, were the result of bait releases by fisherman and were not a part of any management plan (Dill 1944; Roden 1978).

Gammarid amphipods (Gammarus lacustris) were introduced into Bright Angel Creek in 1932 (Carothers and Minckley 1980) and below Hoover Dam in 1941 (Roden 1978). Amphipods are still abundant in the Grand Canyon and below Glen Canyon Dam, but in the lower river are only found in the cold water area above Willow Beach (Roden 1978). Freshwater shrimp, Palaemonetes paludosus, were introduced in Lake Havasu and the Imperial National Wildlife Refuge in 1959 and now exist in scattered populations as far north as Davis Dam (St. Amant and Hulquist 1969).

After the closing of Glen Canyon Dam, Gammarus spp., snails (Physidae and Lymnaeidae), leeches, caddisflies, mayflies and damselflies were introduced into the river below the dam to provide forage for the developing trout fishery (Carothers and Minckley 1980). Similarly, there are proposals to reintroduce stoneflies, caddisflies and mayflies below Hoover Dam to benefit that trout fishery (Beckstrand 1980).

Analysis of fish stomach contents has documented the use of invertebrates as food. Roden (1978) listed some of the more important fish food organisms in Lakes Mead and Mohave (Appendix 9).

Aside from instances of predation on fish fry by aquatic beetles and dragonflies (Usinger 1956), there are few recorded observations of negative impacts to fish populations from invertebrates. Because fish are natural predators on insect larvae, they have been tested as biological control agents for insect pests. Fingerling rainbow trout have been stocked in the Colorado River below Davis Dam to control simuliid flies. Analysis of trout stomach samples from the stocking area showed that 95 percent of the food consumed was simuliid larvae and pupae (Arizona Dept. Game and Fish 1977). This type of program is feasible since simuliid are available to predation during their entire aquatic stage.

Different invertebrate species utilize different habitats. Changes in the river system that remove or modify the available habitats may result in the loss of some members of the invertebrate fauna. An example of this is the loss of mayflies and caddisflies from the river area that became Lake Mohave after the closing of Davis Dam (Jonez and Sumner 1954). Appendix 10 lists some available habitats and the associated fauna.

Invertebrate populations are typically depauperate in the unstable or channelized reaches of the river, consisting of chironomids, Oligochaetes and Corbicula spp. These areas include most of the Topock Gorge, Palo Verde, Cibola and Imperial Divisions (Minckley 1979). The river through the Grand Canyon was similarly depauperate with chironomids, simuliids, oligochaetes, Gammarus spp., physid snails, coriids and veliids taken from the mainstem, and most of these from side eddies (Carothers and Minckley 1980). Backwaters and tributaries supported a richer, more diverse fauna all along the river. Areas below dams also supported sizeable populations of the gravel, riffle inhabiting invertebrates (Minckley 1979). Lake bottoms supported oligochaetes and chironomids (Melancon 1977; Bryant 1978) while shallow, littoral areas showed more diversity. Distribution of the aquatic invertebrate fauna is given in Appendices 7 and 8.

VII. APPENDICES

Appendix 1. Timeline of major events in the development of the Colorado River

1877	First formal filing on Colorado River water by Thomas Blythe
1985	Imperial (or Alamo) Canal begun
1902	Imperial Canal completed
1904	Yuma Project begun
1905	Colorado River flooded Imperial Valley until 1907
	Laguna Diversion Dam begun
1906-24	Levees built and maintained
1907	Yuma Project completed
1909	Laguna Dam completed
1922	Colorado River Compact negotiated - ratified 1929
	Floods in Palo Verde Valley
1931	Boulder Dam begun
1934	Parker Dam begun
	All American Canal begun
1935	Boulder (now Hoover) Dam completed. Lake Mead impounded
1935	(approximately) Colorado River Aqueduct begun
1938	Parker Dam completed. Lake Havasu impounded
	Imperial Dam completed
1941	Headgate Rock Dam begun
1942	Davis Dam begun and halted
	All American Canal completed
1944	Heeadgate Rock Dam completed
1945	Palo Verde Weir constructed
1946	Davis Dam resumed construction
	Colorado River Management Plan formulated
1949	First channelization done from Needles to Topock
1950	Morelos Dam completed
1951-53	Davis Dam completed. Lake Mohave impounded.
1954	Laguna Diversion Dam retired
1955	Topock Desilting Basin begun
1956	Topock Desilting Basin completed
1957	Palo Verde Diversion Dam completed
	All American Canal began water deliveries to Mexico
	Glen Canyon Dam begun
1962	Palo Verde Division channelized
1963	Laguna Desilting Basin begun
	Glen Canyon Dam completed. Lake Powell impounded
1964	Cibola Division channelized
1965	Laguna Desilting Basin completed
1966	Senator Wash Dam and Reservoir completed

Appendix 2. Dredging and channelization in the lower Colorado River 1949-1974.

1949-1951	Needles to Topock channelized
1953-1954	Needles to Big Bend channel begun and halted
1954	Channel relocation above Yuma Bridge
1955-1956	Topock Settling Basin constructed
1956-1960	Needles to Big Bend resumed and completed
1962	Palo Verde Division channelized using terrestrial equipment
1963-1965	Laguna Desilting Basin and outlet channel constructed
1964	Cibola channelization begun
1964-1965	Park Moabi Marina, Topock dredged
1965	Topock Marsh main dike constructed
	dredging at old river mile 603
	Palo Verde Oxbow closure begun
1966	Topock Marsh inlet and outlet structures completed
	Riverside County Marina, Blythe dredged
	Parker I bank stabilization begun
1967	Palo Verde Oxbow inlet and outlet structures completed
	Cibola Dry Cut begun
	Topock Gorge maintenance dredging
1968	Backwater A-10 dredged
	Deer Island Lake begun
	Needles Marina, Needles dredged
	Parker I banks completed
	Palo Verde stabilization completed
1969	Deer Island Lake completed
	Backwater A-7 dredged
	Backwater C-5 dredged
	Yuma channel between Laguna Dam and ORM 669
	Gila Gravity Canal inlet dredged
	Big Bend training structures constructed
1970	Mittry Lake deepened and inlet constructed
	Gila Sluiceway below Imperial Dam dredged
	Cibola Lake dredged for fish and wildlife benefits
	Cibola Dry Cut completed
	Backwater C-5 deepened by dredging
	Backwater A-10 maintenance dredging
	Backwater C-10 dredged
	Palo Verde Oxbow dredged for fish and wildlife benefits
1971	Cibola levee and bank work
	Laguna Settling Basin maintenance dredging
	Mittry Lake maintenance dredging
1972	Park Moabi Marina, Topock maintenance dredging
	Imperial Reservoir dredged
	Backwater C-8 deepened by dredging
1973	Topock Settling Basin maintenance dredging
	Mittry Lake completed
	Laguna maintenance dredging
	ORM 608 and 619 dredged
	Vicinities of Gila Gravity Canal, Gila Sluiceway and Gila River Pilot Channel dredged
1974	Cibola Lake inlet and outlet structures constructed
	Walters Camp in old river channel (Cibola) extended
	Topock Marsh dredged for fish and wildlife benefits

The following maps provide the regional key for the plant and invertebrate species lists.

Appendix Figure 1. Overall map of study area.
2. Detail map of Region 1
3. Detail map of Regions 2 and 3.
4. Detail map of Regions 4 and 5.

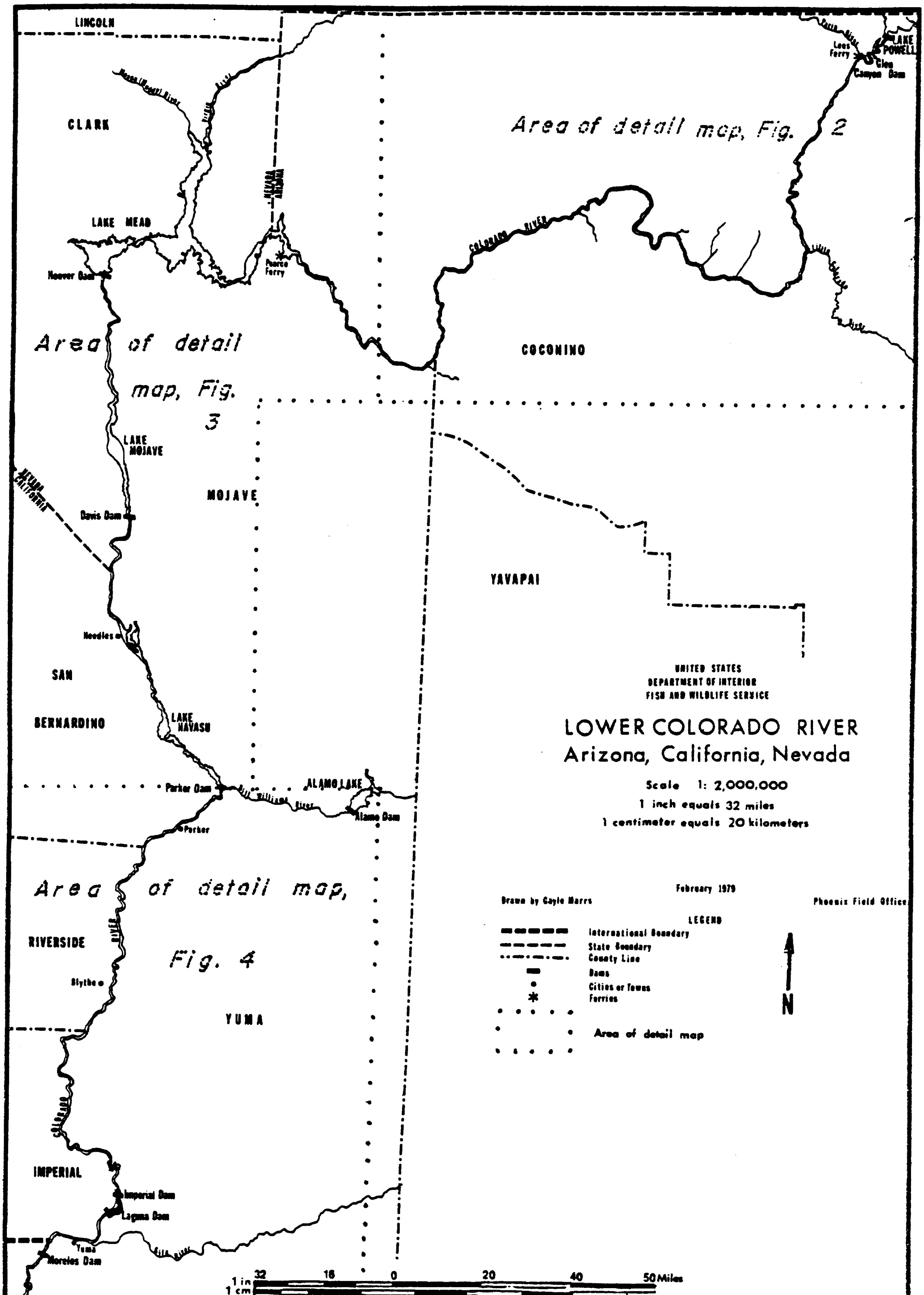
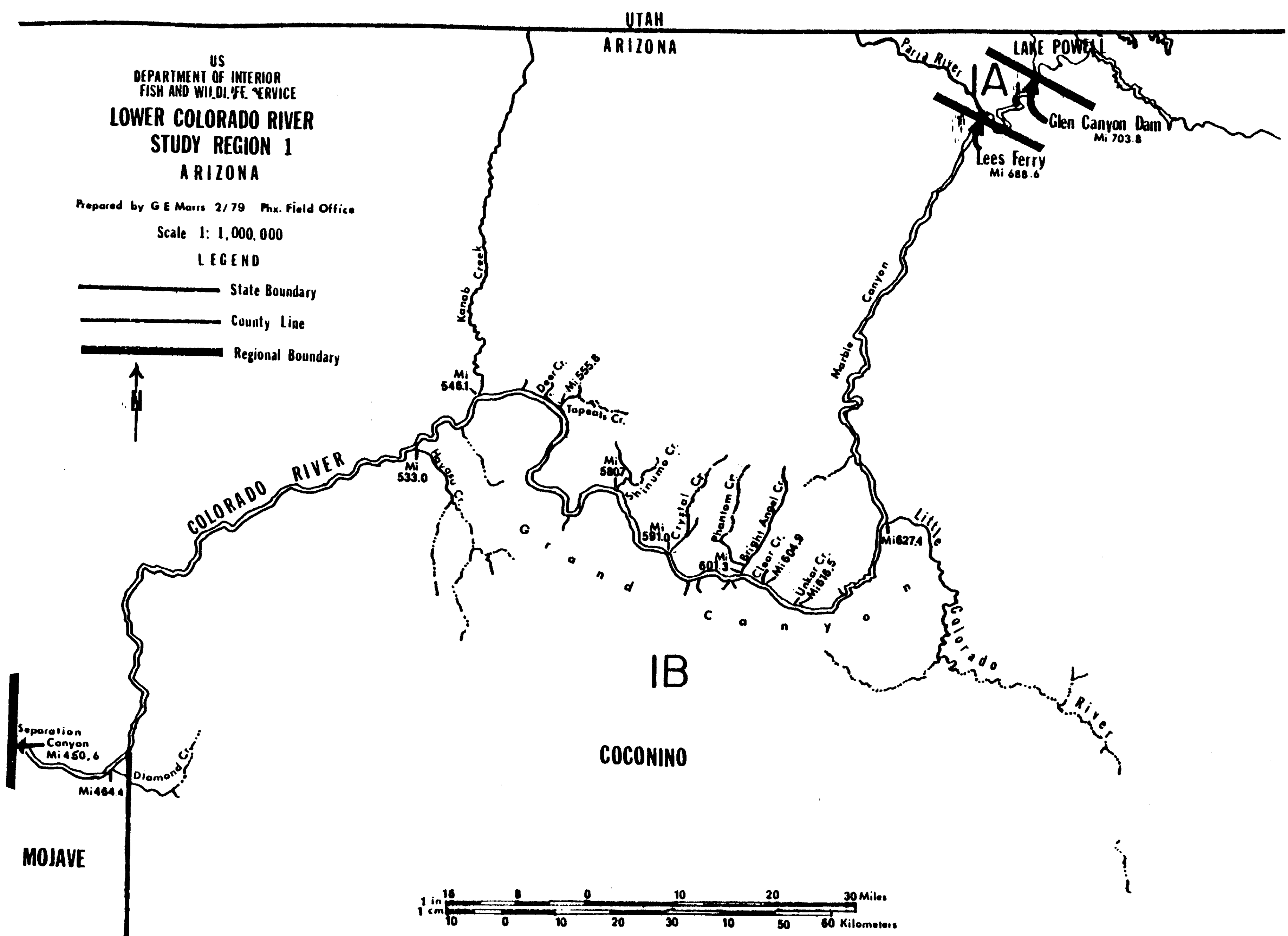

LINCOLN
CLARK
LAKE MEAD
Hoover Dam
Pierce Ferry
Lees Ferry
LAKE POWELL
Glen Canyon Dam
Area of detail map, Fig. 2
COLORADO RIVER
COCONINO
Area of detail map, Fig. 3
LAKE MOJAVE
MOJAVE
Davis Dam
NEVADA
CALIFORNIA
ARIZONA
YAVAPAI
Needles
SAN BERNARDINO
LAKE HAVASU
Parker Dam
ALAMO LAKE
Alamo Dam
Bill Williams River
Parker
Area of detail map, Fig. 4
RIVERSIDE
Blythe
YUMA
IMPERIAL
Imperial Dam
Laguna Dam
Yuma
Morelos Dam
Gila River
UNITED STATES
DEPARTMENT OF INTERIOR
FISH AND WILDLIFE SERVICE
LOWER COLORADO RIVER
Arizona, California, Nevada
Scale 1: 2,000,000
1 inch equals 32 miles
1 centimeter equals 20 kilometers
February 1979
Drawn by Gayle Marrs
Phoenix Field Office
LEGEND
International Boundary
State Boundary
County Line
Dams
Cities or Towns
Ferries
Area of detail map
N
1 in
1 cm
32 16 0 20 40 50 Miles
20 0 20 40 60 80 100 120 Kilometers

Fig. 1



UTAH
ARIZONA
US
DEPARTMENT OF INTERIOR
FISH AND WILDLIFE SERVICE
LOWER COLORADO RIVER
STUDY REGION 1
ARIZONA
Prepared by G E Marrs 2/79 Phx. Field Office
Scale 1: 1,000,000
LEGEND
State Boundary
County Line
Regional Boundary
N
LAKE POWELL
Paria River
IA
Glen Canyon Dam
Mi 703.8
Lees Ferry
Mi 688.6
Marble Canyon
Kanab Creek
Mi 546.1
Deer Cr.
Mi 555.8
Tapeats Cr.
Mi 580.7
Shinumo Cr.
Crystal Cr.
Mi 591.0
Phantom Cr.
Bright Angel Cr.
Mi 601.3
Clear Cr.
Mi 604.9
Unkar Cr.
Mi 616.5
Mi 627.4
Little Colorado River
Mi 533.0
Havasu Cr.
COLORADO RIVER
Grand Canyon
IB
COCONINO
Separation Canyon
Mi 450.6
Diamond Cr.
Mi 464.4
MOJAVE
1 in 16 8 0 10 20 30 Miles
1 cm 10 0 10 20 30 40 50 60 Kilometers

Fig. 2

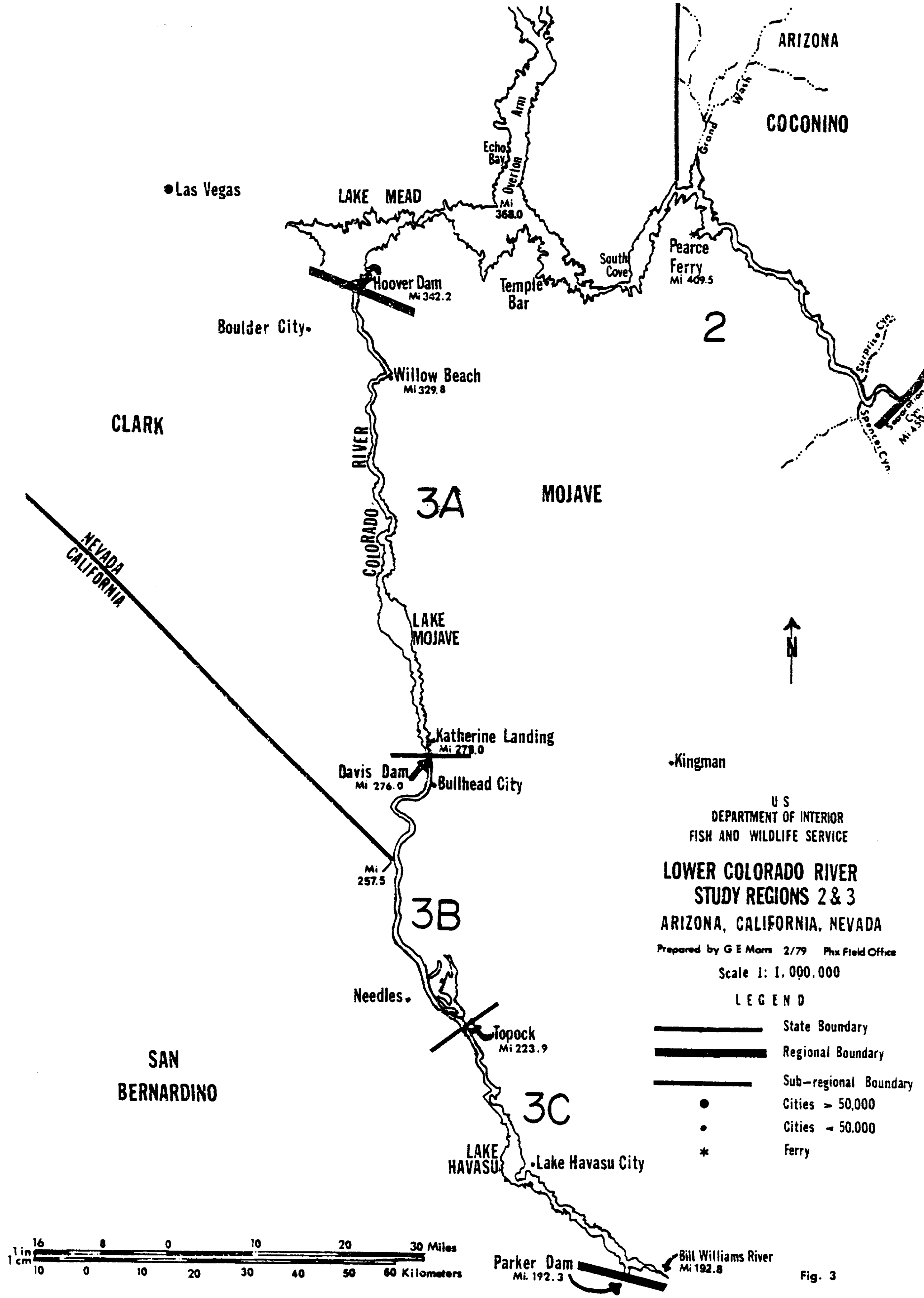
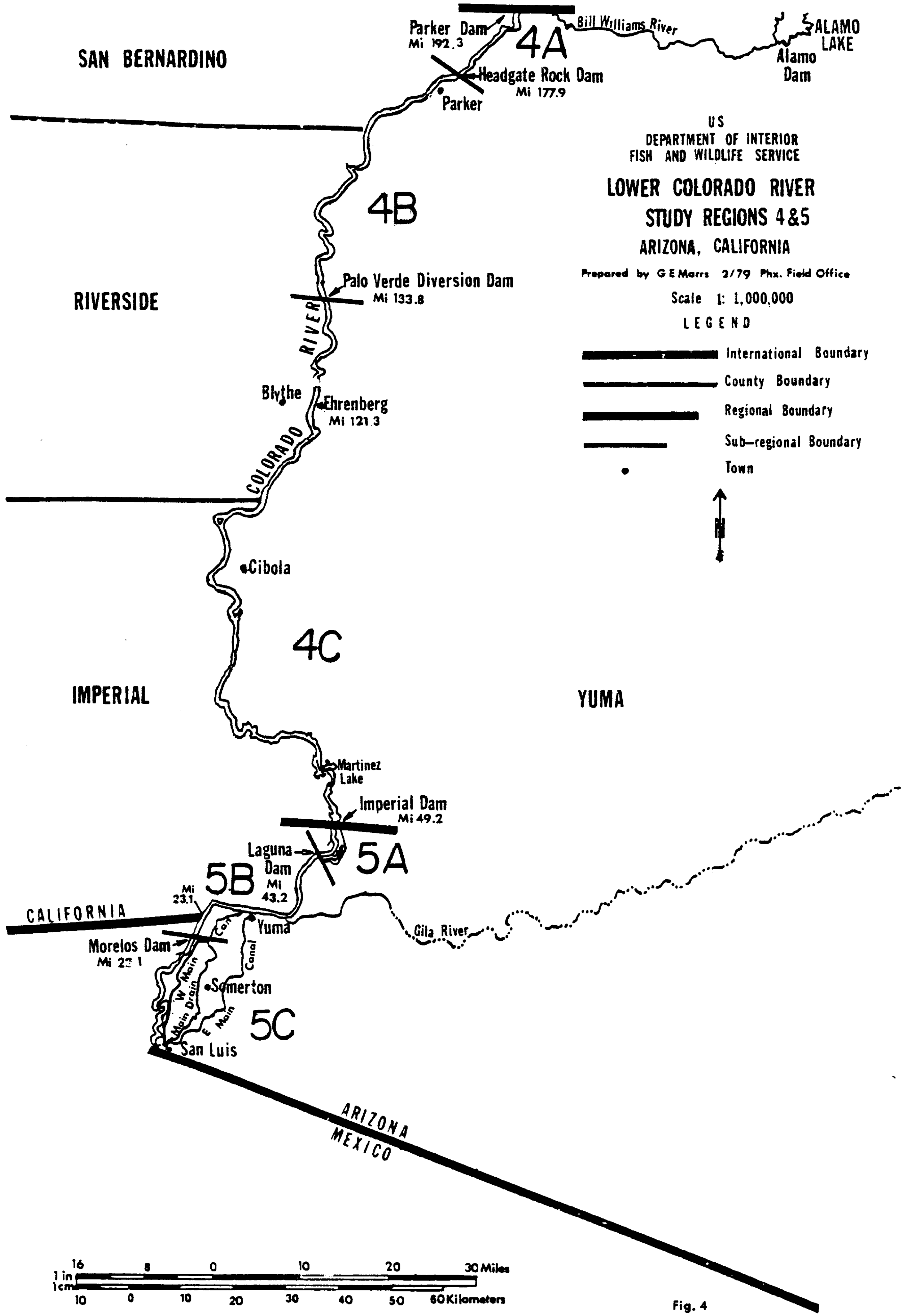

ARIZONA
COCONINO
Grand Wash
Overton Arm
Echo Bay
Las Vegas
LAKE MEAD
Mi 368.0
Pearce Ferry
Mi 409.5
South Cove
Temple Bar
Hoover Dam
Mi 342.2
Boulder City
2
Willow Beach
Mi 329.8
CLARK
COLORADO RIVER
3A
MOJAVE
NEVADA
CALIFORNIA
LAKE MOJAVE
N
Katherine Landing
Davis Dam
Mi 276.0
Bullhead City
Kingman
U S
DEPARTMENT OF INTERIOR
FISH AND WILDLIFE SERVICE
LOWER COLORADO RIVER
STUDY REGIONS 2 & 3
ARIZONA, CALIFORNIA, NEVADA
Prepared by G E Marrs 2/79 Phx Field Office
Scale 1: 1,000,000
LEGEND
State Boundary
Regional Boundary
Sub-regional Boundary
Cities > 50,000
Cities < 50,000
Ferry
Mi 257.5
3B
Needles
Topock
Mi 223.9
SAN BERNARDINO
3C
LAKE HAVASU
Lake Havasu City
Parker Dam
Mi. 192.3
Bill Williams River
Mi 192.8
16 8 0 10 20 30 Miles
10 0 10 20 30 40 50 60 Kilometers
1 in
1 cm

Fig. 3



Parker Dam
Mi 192.3
4A
Bill Williams River
ALAMO LAKE
Alamo Dam
SAN BERNARDINO
Headgate Rock Dam
Mi 177.9
Parker
US
DEPARTMENT OF INTERIOR
FISH AND WILDLIFE SERVICE
LOWER COLORADO RIVER
STUDY REGIONS 4&5
ARIZONA, CALIFORNIA
Prepared by G E Marrs 2/79 Phx. Field Office
Scale 1: 1,000,000
LEGEND
International Boundary
County Boundary
Regional Boundary
Sub-regional Boundary
Town
N
4B
Palo Verde Diversion Dam
Mi 133.8
RIVERSIDE
RIVER
Blythe
Ehrenberg
Mi 121.3
COLORADO
Cibola
4C
IMPERIAL
YUMA
Martinez Lake
Imperial Dam
Mi 49.2
Laguna Dam
Mi 43.2
5A
5B
Mi 23.1
CALIFORNIA
Yuma
Gila River
Morelos Dam
Canal
W. Main
Main Drain
Somerton
E. Main
5C
San Luis
ARIZONA
MEXICO
16 8 0 10 20 30 Miles
1 in
1cm
10 0 10 20 30 40 50 60 Kilometers

Fig. 4

Appendix 3. Algal groups from the Colorado River

Species	Region	Location	Date	Reference
CHLOROPHYTA				
Charophyceae	1A	Above Lee Ferry	1980	232
Chara sp.	1B	Grand Canyon tributaries	1977-78	72
	3A	Lake Mohave	1954	193
	3B	Topock Gorge Division	1974-76	256
	3B	Topock Marsh	1980	104
	3C	Havasu Division	1974-76	256
	4A,B	Parker Division	1974-76	256
	4B	Deer Island Lake	1974	319
	4C	Palo Verde Division	1974-76	256
	4B,C	Riverside County, CA	ND	18
	4C	Imperial Division	1974-76	256
	5A	Laguna Division	1974-76	256
	5B,C	Yuma-Limitrophe	ND	18
	5C	Limitrophe-Hunter's Hole	1974	258
	5C	Limitrophe Division	1974-76	256
CHLOROPHYCEAE				
Cladophora glomerata	1	Lee Ferry to Lake Mead	1977-78	72
	1	Lee Ferry to Diamond Creek (Rm 464.5)	1975	85
	2	Lake Mead, Gregg Basin	1968	396
	2	Hoover Dam	1973	124
	3A	Hoover Dam to Willow Beach	1941	259
	3A	Black Canyon	1979-80	294
	3A	Lake Mohave	1954	193
	3B	Below Davis Dam	1954	193
	3B	Mohave Valley Division	1974-76	256
	3B	Topock Gorge Division	1974-76	251
	3C	Lake Havasu	1973	124
	4B	Colorado River Indian Reservation (Parker Div.)	1968	396
	4C	Palo Verde Division	1974-76	256
	4C	Cibola Division	1974-76	256
	4C	Imperial Division	1974-76	256
Pseudovella sp.	4C	Imperial Division	1974-76	256
	5C	Limitrophe Division	1974-76	256

Species	Region	Location	Date	Reference
Stigeoclonium tenule	3A	Black Canyon	1979-80	294
filamentous green algae	1A	Glen Canyon	1958	239
	1B	Grand Canyon	1977-78	72
	2	Lake Mead	1954	193
	3A	Hoover Dam to Willow Beach	1941	259
	3A	Lake Mohave	1980	130
	3C	Lake Havasu	1957	199
	4A	Lake Havasu to Headgate Rock Dam	1957	199
	4C	Palo Verde Division	1974-76	256
	4C	Cibola Division Channel	1974-76	256
	4C	Imperial Division backwaters Velian L	1971	226
	4C	Imperial Division backwaters Draper L Velian L Senator Wash Res.	1975	305
	5C	Limitrophe Division Gadsen Lakes	1974-76	256
Rhizophora sp.	3B	Mohave Valley Division	1974-76	256
Chlorophyta sp.	1B	Grand Canyon and tributaries	1975-76	355
	1B	Grand Canyon and tributaries	1975-76	94
	2	Lake Mead	1954	193
	2	Lake Mead	1977-78	296
	2	Lake Mead	1980	314
	3A	Black Canyon	1979	294
	3A	Lake Mohave	1954	193
	3A	Lake Mohave	1976-77	296
	3A	Lake Mohave	1977	307

Species	Region	Location	Date	Reference
CHRYSOPHYTA				
Bacillariophyceae	1B	Grand Canyon and tributaries	1975-76	94
	1B	Grand Canyon and tributaries	1975-76	355
	2	Lake Mead	1977-78	296
	2	Lake Mead	1980	293
	3A	Black Canyon	1979	294
	3A	Lake Mohave	1976-77	296
	3A	Lake Mohave	1977	307
	3B	Mohave Valley Division	1974-76	256
	3B	Topock Gorge Division	1974-76	256
	4C	Cibola backwaters	1974-76	256
Cryptophyta	1B	Grand Canyon and tributaries	1975-76	355
	1B	Grand Canyon and tributaries	1975-76	94
	2	Lake Mead	1977-78	296
	3A	Lake Mohave	1976-77	296
	3A	Lake Mohave	1977	307
Cyanophyta	1B	Grand Canyon and tributaries	1975-76	355
	1B	Grand Canyon and tributaries	1975-76	94
	2	Lake Mead	1954	193
	2	Lake Mead	1977-78	296
	2	Lake Mead	1980	314
	3A	Hoover Dam to Willow Beach	1941	259
	3A	Lake Mohave	1954	193
	3A	Lake Mohave	1976-77	296
	3A	Lake Mohave	1977	307
	3B	Topock Marsh	1968	146
	3,4,5	Colorado River Channel	1974-76	256
	3B	Mohave Valley Division	1974-76	256
	3B	Topock Gorge Division	1974-76	256
	4C	Cibola Division backwaters	1974-76	256
	4C	Imperial Reservoir lakes	1971	417
	5A	Laguna Division	1974-76	256
	5B	Yuma Division	1974-76	256
	5C	Limitrophe Division	1974-76	256

Species	Region	Location	Date	Reference
Phaeophyta	3A	Lake Mohave	1954	193
	3A	Lake Mohave	1980	104
	4C	Imperial Division Velian L	1971	226
	4C	Imperial Division Velian L	1975	305
Phodophyta	1B	Grand Canyon and tributaries	1975-76	94
	4C	Imperial Division	1974-76	256
	5C	Limitrophe Division	1974-76	256
Xanthophyta	1B	Grand Canyon and tributaries	1975-76	94

APPENDIX 4. Aquatic Vascular Plants of the Colorado River

Species	Region	Location	Date	Reference
CERATOPHYLLACEAE				
Ceratophyllum demersum	3B	Mohave Valley Division	1974-76	256
	3B	Topock Gorge Division	1974-76	256
	3C	Havasu Division	1974-76	256
	4A,B	Parker Division	1974-76	256
	4C	Palo Verde Division	1974-76	256
	4C	Pilot Cut and Palo Verde Outfall, Cibola NWR	1980	104
	4C	Imperial Division	1974-76	256
	4C	Imperial Division backwaters	1971	226
		Draper L.		
		#4		
		#15		
	4C	Imperial Division backwaters	1975	305
		Draper L.		
		#4		
		#15		
	5A	Laguna Division	1974-76	256
	5B	Yuma Division	1974-76	256
	5C	Limitrophe Canals	1974-76	256
	5	Yuma to Limitrophe	ND	18
	3,4,5	Lower Colorado River	1951	87
Ceratophyllum sp.	4A,B	Parker Division	1964	389
HALORAGACEAE				
Myriophyllum brasiliense	3A	Lake Mohave RM 330.4	1980	105
		319.4		
		318.9		
		317.9		

Species	Region	Location	Date	Reference
	4A,B	Parker Division	1974-76	256
	4A	Headgate Rock Dam	1980	105
	4B,C	Colorado River Indian Reservation	1980	104
	4C	Palo Verde Division	1965	209
	4C	Pilot Cut and Palo Verde Outfall, Cibola NWR	1980	104
	5B	Canals and drains - Yuma	1974-76	256
<u>Myriophyllum spicatum exalbescens</u>	4A	Moovalya L., Parker Division	1974-75	256
	4B	Deer Island Lake, Parker Division	1974	319
	4A,B	Parker Division	1974-76	256
	4C	Backwater A-7, Palo Verde Division	1972	405
	5B,C	Yuma to Limitrophe	ND	18
	5B	Yuma-Canals and Drains	1974-76	256
<u>Myriophyllum</u> sp.	4A,B	Parker Division	1964	389
	4C	Imperial Division backwaters Draper L. Taylor L. #4 #5 Devil L. Ferguson L. #9 #10 #12 Senator L. #15 Squaw L.	1971	226

Species	Region	Location	Date	Reference
	4C	Taylor Lake	1971	303
	4C	Imperial Division backwaters	1975	305
		Draper L.		
		Taylor L.		
		#4		
		#5		
		Devil L.		
		Ferguson L.		
		#9		
		#10		
		#11		
		#12		
		Senator L.		
		#15		
		Squaw L.		
HYDROCHARITACEAE				
Elodea canadensis	1A	Above Lee Ferry	1980	232
	1B	Grand Canyon	1977-78	72
		RM 688.6-658.1		
		RM 557.7-546.1		
	3A	Hoover Dam to Willow Beach	1941	259
	3A	Lake Mohave	1950's	19
NAJADACEAE				
Najas guadalupensis	3B	Topock Gorge Division	1974-76	256
	4A	Moovalya Lake, Havasu Division	1974-75	256
	4A,B	Parker Division	1964	389
Najas marina	2	Lake Mead	1962	272
	2	Lake Mead	1968	274
	2	Lake Mead - Overton Arm	1972	416
	2	Lake Mead - Little Gyp Beds	1980	287
		Swallow Bay		
		Burro Pt.		
		Quail Bay		

Species	Region	Location	Date	Reference
	2	Lake Mead	1980	232
	3A	Lake Mohave - Klondyke Cove	1979	286
	3A	Lake Mohave	1980	287
	3A	Lake Mohave - RM 330.4	1980	105
		319.4		
		318.9		
		317.9		
	3B	Ft. Mohave	1940	405
	3B	Ft. Mohave to Topock	1950's	19
	3B	Topock Mud flats	1960's	405
	3B	Topock Marsh	1968	146
	3B	Topock Marsh	1980	104
	3B	Beal Lake, Topock	1969	14
	3B	Mohave Valley Division	1974-76	256
	3C	Topock to Parker Dam	1950's	19
	3B	Topock Gorge backwaters	1972-74	227
	3B	Topock Gorge Division	1974-76	256
	3C	Lake Havasu	1938-50	42
	3C	Lake Havasu	1972	393
	3C	Lake Havasu	1972	219
	3C	Havasu NWR	ND	293
	3C	Bill Williams Arm, Lake Havasu	1980	104
	3C	Havasu Division	1974-76	256
	4A	Moovalya L., Havasu Division	1974-75	256
	4B	Deer Island L., Parker Division	1971	15
	4B	Deer Island L., Parker Division	1974	319
	4C	Pilot Cut and Palo Verde Outflow, Cibola NWR	1980	104
	4C	Cibola Division	1974-76	256
	4C	Imperial Division	1961	20
		Martinez L.		
		No Name 1		
		No Name 2		
	4C	Imperial Reservoir	1969-72	152
	4C	Imperial Reservoir	1971	153
	4C	Imperial Reservoir Lakes	1971	417

Species	Region	Location	Date	Reference
	4C	Imperial Backwater Lakes	1971	226
		Draper L.		
		Taylor L.		
		#4		
		#5		
		#6		
		Devil L.		
		Ferguson L.		
		#9		
		#10		
		#11		
		#12		
		Senator L.		
		#15		
		Squaw L		
	4C	Imperial Backwater Lake	1971	303
		Taylor Lake		
	4C	Imperial backwater lakes	1975	305
		Draper L.		
		Taylor L.		
		#4		
		#5		
		#6		
		Devil L.		
		Ferguson L.		
		#9		
		#10		
		#11		
		#12		
		Senator L.		
		#15		
		Squaw L.		
	5C	Laguna Division	1974-76	256
	5B	Haughtin L. (CA) Yuma Division	1943	405
	5B	Yuma Division	1974-76	256

Species	Region	Location	Date	Reference
	5B,C	Yuma to Limitrophe	ND	18
	5C	Hunter's Hole, Limitrophe Division	1974	258
	5C	Gadsen Lakes, Limitrophe Division	1974-76	256
	5C	Limitrophe Division	1974-76	256
POTAMOGETONACEAE				
Potamogeton crispus	1B	Elves Chasm - RM 572.8	1977-78	72
	4A,B	Parker Division	1964	389
	4B,C	Colorado River Indian Reservation	1980	104
	4B	Parker - RM 175.6	1980	105
Potamogeton diversifolius	1B	Grand View Trail	1916	405
	1B	Grand Canyon	ND	72
Potamogeton foliosus	1B	Havasu Canyon	1938	70
	1B	Havasu Creek	1940	405
	1B	Mooney Falls, Havasu Creek	1941	405
	1B	Havasu Creek	1943	405
	1B	Havasu Canyon	1950	405
	1B	Havasu Creek	1950	406
	1B	Grand Canyon	1976	71
	1B	Grand Canyon	1977-78	72
	4C	Imperial Division	1974-76	256
	3,4,5	Canals and drains - lower Colorado River	1974-76	256
	5C	Limitrophe Division	1974-76	256
Potamogeton natans	1B	Grand Canyon	1977-78	72
Potamogeton nodosus	4C	Imperial NWR Adobe Lake	1956	405
Potamogeton pectinatus	1B	Little Colorado River - RM 627.4	1977-78	72
	1B	Elves Chasm - RM 572.8	1977-78	72
	2	Lake Mead - Little Gyp Beds	1979	287
	2	Lake Mead	1980	232
	3A	Lake Mohave	1954	193

Species	Region	Location	Date	Reference
	3A	Lake Mohave - RM 330.4	1979	105
		319.4		
		318.9		
		317.9		
	3B	below Davis Dam	1954	193
	3B	Mohave Valley Division	1974-76	256
	3B	Ft. Mohave to Topock	1950's	19
	3B	Beal Lake - Topock Marsh	1969	14
	3B	Topock Marsh	1980	104
	3B	Topock Gorge Division	1974-76	256
	3C	Topock to Parker Dam	1950's	19
	3C	Lake Havasu	1954	42
	3C	Lake Havasu	1971	392
	3C	Lake Havasu	1972	393
	3C	Havasu NWR	ND	293
	3C	Bill Williams Arm, Lake Havasu	1980	104
	4A	Parker Dam to Headgate Rock Dam	1950's	19
	4A	below Parker Dam	1974-76	256
	4A	Moovalya Lake - Havasu Division	1974-75	159
	4B	Parker Strip - RM 185.4 - 181.0	1980	105
	4A,B	Parker Division	1964	389
	4A,B	Parker Division	1974-76	256
	4A	Headgate Rock Dam	1980	105
	4B,C	Colorado River Indian Reservation	1980	104
	4C	Palo Verde Division	1974-76	256
	4C	Pilot Cut and Palo Verde Outlet, Cibola NWR	1980	104
	4C	Imperial Division		
		Martinez Lake	1961	20
		No Name #1	1961	20
		No Name #2	1961	20
		backwaters	1971	226
		Draper L.		
		Velian L.		
		Taylor L.		
		#4		
		#6		
		Devil L.		
		Ferguson L.		

Species	Region	Location	Date	Reference
Ruppia maritima	3C	Topock to Parker Dam	1950's	19
	4A,B	Parker Division	1964	389
AANNICHELLIACEAE				
Zannichellia palustris	1B	Grand Canyon	1977-78	72
		RM 688.6 - 658.1		
		RM 557.7 - 546.1		
		Little Colorado River, RM 627.4		
		Elves Chasm, RM 572.8		
		Deer Creek, RM 553.2		
	2	Lake Mead	1980	232
	3A	Lake Mohave	1954	193
	3A	Lake Mohave	1980	130
	3B	Topock Gorge Division	1974-76	256
	4B,C	Riverside County, California	ND	18
	4C	Imperial Division	1974-76	256
	5C	Limitrophe Division	1974-76	256

Appendix 5. Major Emergent and Riparian Plant Species

Species	Location	Year	Region	Reference
TYPHACEAE				
Typha angustifolia	Bridge Canyon - Grand Canyon (RM 455.1)	1979	1B	172
	Lake Mead	1977	2	107
	Lake Mead	1980	2	232
	Beach below Hoover Dam	1979	3A	172
	Lake Mohave	1954	3A	193
	Imperial Division lakes	1961	4C	20
	Martinez L.			
	Mittry L.			
	No Name 1			
	No Name 2			
	Yuma County	1959	4,5	405
Typha domingensis	Grand Canyon		1B	
	RM 688.6 - 658.1	1977-78		72
	Paria River (RM 688.4)	1977-78		72
	RM 658.1 - 647.9	1977-78		72
	Old River Mile 37.8	1980		140
	Buck Farm (RM 647.9)	1977-78		72
	Old River Mile 53.0	1980		140
	RM 647.9 - 627.4	1977-78		72
	Little Colorado River (RM 627.4)	1977-78		72
	RM 627.4 - 604.9	1977-78		72
	Old River Mile 61.5	1980		140
	Old River Mile 65.5	1980		140
	Unkar (RM 616.5)	1977-78		72
	Clear Creek (RM 604.9)	1977-78		72
	RM 604.9 - 580.7	1977-78		72
	Bright Angel Creek (RM 601.3)	1977-78		72
	Pipe Creek (RM 600.2)	1977-78		72
	Hermit Creek (RM 594.4)	1977-78		72
	Crystal Creek (RM 590.8)	1977-78		72
	RM 580.7 - 557.7	1977-78		72
	Shinumo Creek (RM 580.7)	1977-78		72
	Elves Chasm (RM 572.8)	1977-78		72
	RM 557.7 - 546.1	1977-78		72

Species	Location	Year	Region	Reference
	Tapeats Creek (RM 555.8)	1977-78		72
	Old River Mile 143.7	1980		140
	RM 546.1 - 523.3	1977-78		72
	Old River Mile 156.5	1980		140
	Havasu Canyon 533.0			
	Mooney Falls	1940		405
	Mooney Falls	1946		406
	Havasu Creek	1950		405
	Havasu Creek	1952		406
	Havasu Creek	1976		70
	RM 474.4 - 464.4	1977-78		72
	Diamond Creek (RM 464.4)	1977-78		72
	RM 464.4 - 450.6	1977-78		72
	Grand Canyon	1892	1B	405
	Grand Canyon	1913	1B	405
	Grand Canyon	1975	1B	203
	Old River Mile 246.0	1980	2	140
	Lake Mead	1977	2	107
	Lake Mead	1980	2	232
	San Bernadino County, CA	ND	3,4	18
	Moovalya Pond - Havasu Division	1974	4A	256
	Riverside County, CA	ND	4B,C	18
	Imperial Division	1961	4C	20
	Martinez L.			
	Mittry L.			
	No Name 1			
	No Name 2			
	Imperial Dam			
	Laguna Division - Bard, CA	1912	5A	405
	Yuma Division canals	1974-76	5B	256
	Gila River at Yuma	1960	5B	405
	Hunter's Hole Limitrophe Division	1974	5C	258
Typha latifolia	Grand Canyon	1975	1B	203
	Grand Canyon	1976	1B	70

Species	Location	Year	Region	Reference
	Grand Canyon		1B	
	Paria River (RM 688.4)	1977-78		72
	RM 658.1 - 627.4	1977-78		72
	Old River Mile 65.5	1980		140
	Bright Angel Creek (RM 601.3)	1977-78		72
	Hermit Creek (RM 594.4)	1977-78		72
	Kanab Creek (RM 546.1)	1977-78		72
	Havasu Creek (RM 533.0)	1977-78		72
	Havasu Canyon (RM 533.0)	1976		70
	Old River Mile 156.5	1980		140
	Lava Falls Spring (RM 510.6)	1977-78		72
	Old River Mile 179.0	1980		140
	Three Springs Canyon (RM 474.4)	1977-78		72
	Diamond Creek (RM 464.4)	1977-78		72
	Lake Mead	1968	2	274
	Topock Marsh	1968	3B	146
	Havasu National Wildlife Refuge	ND	3C	293
	Deer Island Lake - Parker Division	1975	4B	320
	Imperial Reservoir	1971	4C	417
	Imperial Reservoir	1971	4C	153
	Imperial Reservoir	1969-72	4C	152
Typha sp.	Above Lee Ferry	1980	1A	232
	Grand Canyon	1980	1B	386
	Lake Mead	1967	2	273
	Lake Mead	1980	2	295
	Lake Mead - Swallow Bay	1980	2	287
	Burro Pt.			
	Quail Bay			
	Hoover Dam to Willow Beach	1943	3A	259
	Lake Mohave	1980	3A	130
	Mohave Valley Division	1974-76	3B	256
	Topock	1967	3B	145
	North of Topock Gorge	1965	3B	208
	Topock Gorge Division	1974-76	3B	256
	Topock Marsh	1980	3B	104
	Topock Gorge backwaters	1976	3B	227

Species	Location	Year	Region	Reference
	Havasu Division - Bill William R.	1974-76	3C	256
	Bill Williams Arm	1980	3C	104
	Below Parker Dam	1974-76	4A	256
	Parker Division	1967	4A,B	13
	Parker Division	1974-76	4A,B	256
	Deer Island Lake	1971	4B	15
	Palo Verde Division	1974-76	4C	256
	Cibola Division	1974-76	4C	256
	Pilot Cut and Palo Verde Outflow, Cibola NWR	1970	4C	104
	Imperial Division backwaters	1971	4C	226
	Imperial Division backwaters	1975	4C	305
	Imperial Division	1974-76	4C	72
	Laguna Division	1974-76	5A	72
	Yuma to Limitrophe	ND	5B,C	18
	Yuma Division	1974-76	5B	256
	Yuma canals and drains	1974-76	5B	256
	Limitrophe Division	1974-76	5C	256
	Upper Limitrophe	1976	5C	35
	Middle and lower Limitrophe	1976	5C	35
	Hunter's Hole, Limitrophe Division	1974-76	5C	256
POACEAE				
Arundo donax	Grand Canyon - Phantom Ranch ORM 156.5	1966	1B	406
	Bright Angel Creek RM 601.3	1977-78	1B	72
	Lower Colorado River	1974-76	3,4,5	256
	Topock Gorge Division	1974-76	3B	256
	San Bernadino County, CA	ND	3,4	18
	Palo Verde Division	1974-76	4C	256
	Cibola Division	1974-76	4C	256
	Riverside County, CA	ND	4B,C	18
	Imperial Division	1974-76	4C	256
	Laguna Division	1974-76	5A	256
	Limitrophe Division	ND	5C	18
	Limitrophe Division - Hunter's Hole	1974-76	5C	256

Species	Location	Year	Region	Reference
Phragmites australis	Above Lee Ferry	1980	1A	232
	Grand Canyon		1B	
	Lee Ferry (RM 688.6)	1980		140
	Paria River (RM 688.0)	1977-78		72
	Nankoweap (RM 636.4)	1977-78		72
	Old River Mile 52.4	1976		70
	Old River Mile 54.5	1980		140
	Little Colorado River (RM 627.4)	1977-78		72
	Old River Mile 61.5	1980		140
	Unkar (RM 616.5)	1973		405
	Unkar (RM 616.5)	1977-78		72
	Old River Mile 71.0	1976		70
	Old River Mile 71.0	1980		140
	Old River Mile 73.0	1980		140
	Old River Mile 83.5	1980		140
	Bright Angel Creek (RM 601.3)	1916		405
	Bright Angel Creek (EM 601.3)	1977-78		72
	Old River Mile 87.8	1980		140
	Old River Mile 89.0	1980		140
	Old River Mile 98.0	1980		140
	Shinumo Creek (RM 580.7)	1906		405
	Old River Mile 109	1980		140
	Elves Chasm (RM 116.5)	1977-78		72
	Deer Creek (RM 553.2)	1970		405
	Deer Creek (RM 553.2)	1977-78		72
	Old River Mile 136.2	1980		140
	Old River Mile 149.5	1980		140
	Old River Mile 156.5	1980		140
	Lava Falls Spring (RM 510.6)	1977-78		72
	Old River Mile 179.0	1980		140
	Old River Mile 194.8	1972		405
	Parashont Creek (RM 488)	ND		405
	Old River Mile 200.3	1980		140
	Old River Mile 209.0	1976		70
	Old River Mile 209.0	1980		140
	Three Springs Canyon (RM 474.4)	1977-78		72
	Old River Mile 225.0	1980		140
	Diamond Creek (RM 464.4)	1972		405

Species	Location	Year	Region	Reference
	Lee Ferry to Lake Mead (RM 688.6 - 450.6)	1977-78	1B	72
	Lee Ferry to Lake Mead (RM 688.6 - 450.6)	1980	1B	386
	Lake Mead	1980	2	232
	Lake Mead	1977	2	107
	Old River Mile 268	1976		70
	Old River Mile 268	1980		140
	Old River Mile 275.0	1976		70
	Old River Mile 275.0	1980		140
	8 miles up from Pierce Ferry	1973		405
	Rampart Cave	1979	2	172
	Hoover Dam to Willow Beach	1943	3A	259
	Lower Colorado River	ND	3,4,5	18
	Parker Division	1967	4A,B	13
	Parker Division	1974-76	4A,B	256
	Imperial Division Lakes	1961	4C	20
	Martinez L.			
	Mittry L.			
	No Name 1			
	No Name 2			
	Imperial Reservoir	1971	4C	153
	Imperial Division backwater	1971	4C	226
	Draper L.			
	Velian L.			
	Taylor L.			
	#4			
	#5			
	#6			
	Devil L.			
	Ferguson L.			
	#9			
	#10			
	#11			
	#12			
	Senator L.			
	#15			
	Squaw L.			
	Imperial Division	1974-76	4C	256

Species	Location	Year	Region	Reference
	Imperial Division backwaters	1975	4C	305
	Draper L.			
	Velian L.			
	Taylor L.			
	#4			
	#5			
	#6			
	Devil L.			
	Ferguson L.			
	#9			
	#10			
	#11			
	#12			
	Senator L.			
	#15			
	Squaw L.			
	Yuma Valley Canals	1927	5B	405
	Old Yuma crossing	1975	5B	405
	Upper Limitrophe Division	1976	5C	35
	Hunter's Hole - Limitrophe Division	1974	5C	258
CYPERACEAE				
Carex albonigra	Grand Canyon ORM 5.6	1980	1B	140
	Grand Canyon ORM 28.7	1976	1B	70
Carex aquatilis	Grand Canyon	1977-78	1B	72
	RM 688.6 - 627.4			
	Paria River (RM 688.4)			
	Vasey's Paradise (RM 658.1)			
	Bright Angel Creek (RM 601.3)			
Carex canescens	Grand Canyon	1980	1B	140
	ORM 32.0			
	ORM 41.0			
	ORM 61.5			

Species	Location	Year	Region	Reference
Carex curatorum	False President Harding Rapids	1974	1B	405
	Grand Canyon ORM 28.7	1976	1B	70
	Grand Canyon	1980	1B	140
	ORM 41.0			
	ORM 87.0			
Carex hystricina	Grand Canyon	1977-78	1B	72
	Vasey's Paradise (RM 658.1)			
	Clear Creek (RM 604.9)			
	Bright Angel Creek (RM 601.3)			
	Pipe Creek (RM 600.2)			
	Hermit Creek (RM 594.4)			
	Grand Canyon ORM 95.0	1980	1B	140
Carex lanuginosa	Above Lee Ferry	1980	1A	232
Carex nebraskensis	Above Lee Ferry	1980	1A	232
	Grand Canyon RM 688.6 - 658.1	1977-78	1B	72
Carex senta	Grand Canyon - Vasey's Paradise (RM 658.1)	1973	1B	405
	Grand Canyon - ORM 5.6	1980	1B	140
	ORM 31.7			
	ORM 32.0			
Carex subfusca	Grand Canyon ORM 274.3	1980	1B	140
	2 miles up from Emory Falls (L. Mead)	1979	2	172
	Lake Mead	1977	2	107
Carex thurberi	Grand Canyon ORM 88.7	1980	1B	140
	ORM 89.0			
	Grand Canyon Bright Angel Creek	1939	1B	405
Cladium californicum	Grand Canyon		1B	
	Unkar (RM 616.5)	1977-78		72
	Hermit Creek (RM 594.4)	1977-78		72
	RM 557.7 - 546.1	1977-78		72

Species	Location	Year	Region	Reference
	Stone Creek (RM 557.7)	1977-78		72
	ORM 133.5	1980		140
	155 mile canyon (RM 539.7)	1977-78		72
	RM 523.3 - 474.4	1977-78		72
	Lava Falls Spring (RM 510.6)	1977-78		72
	ORM 166	ND		405
	ORM 179 Lava Falls	1980		140
	Lake Mead	1977	2	107
	ORM 235.0	1980		140
	ORM 269.0	1980		140
	ORM 270.0	1974		405
	ORM 274.0	1976		70
	ORM 274.0	1980		140
	ORM 274.3	1980		140
Cladium mariscus var. *californicum*	Grand Canyon - Hermit Creek (RM 594.4)	1970	1B	405
	Lake Mead - 2 miles above Emory Falls	1939	2	405
Eleocharis caribaea	Parker Division	ND	4A,B	18
	Backwater A-7 Palo Verde Division	1970	4C	405
	Adobe Ruins - Cibola/Imperial Division	ND	4C	18
	Limitrophe Division	ND	5C	18
Eleocharis bella	Yuma County	ND	4,5	18
Eleocharis macrostachya	Above Lee Ferry	1980	1A	232
	Grand Canyon		1B	
	Vasey's Paradise (RM 658.1)	1977-78		72
	RM 627.4 - 604.9	1977-78		72
	155 Mile Canyon (RM 539.7)	1977-78		72
	Lava Falls (RM 510.6)	1930		405
	ORM 179.0	1980		140
	Yuma	1912	5B	405
Eleocharis parishii	Grand Canyon RM 557.7 - 546.1	1977-78	1B	72

Species	Location	Year	Region	Reference
Eleocharis parvula	Yuma - Limitrophe	ND	5B,C	18
Eleocharis rostellata	Grand Canyon - Little Colorado River	1977-78	1B	72
	Grand Canyon ORM 179	1980	1B	140
	Lake Mead	1977	2	107
Fimbristylus thermalis	ORM 87.0	1976	1B	70
Scirpus americanus	Above Lee Ferry	1980	1A	232
	Grand Canyon	1977-78	1B	72
	RM 688.6 - 604.9			
	Paria River (RM 688.4)			
	Vasey's Paradise (RM 658.1)			
	Little Colorado River (RM 627.4)			
	Bright Angel Creek (RM 601.3)			
	Pipe Creek (RM 600.2)			
	Elves Chasm (RM 572.8)			
	Kanab Creek (RM 546.1)			
	RM 523.3 - 508.6			
	Lake Mead	1976	2	107
	Riverside County, CA	ND	4B,C	18
Scirpus acutus	Grand Canyon	1975	1B	203
	RM 688.6 - 647.9	1977-78		72
	Paria River (RM 688.4)	1977-78		72
	ORM 5.6	1980		140
	ORM 28.8	1980		140
	ORM 50.0	1980		140
	ORM 52.5	1980		140
	ORM 61.5	1980		140
	RM 627.4 - 604.9	1977-78		72
	Little Colorado River (RM 627.4)	1977-78		72
	ORM 116.5	1976		70
	ORM 116.5	1980		140
	Kanab Creek (RM 546.1)	1977-78		72
	155 Mile Canyon (RM 539.1)	1977-78		72
	RM 523.3 - 474.1	1977-78		72

Species	Location	Year	Region	Reference
	Lake Mead	1980	2	287
	Burro Pt.			
	Swallow Bay			
	Quail Bay			
	Lake Mead	1980	2	232
	Backwater A-7 Palo Verde Division	1972	4C	405
	Imperial National Wildlife Refuge	ND	4C	18
	Meers Pt. Imperial NWR	1970		405
	Imperial Division	1961	4C	20
	Martinez L.			
	Mittry L.			
	No Name 1			
	No Name 2			
	Imperial Dam Reservoir			
Scirpus californicus	ORM 230.0	1980	1B	140
	Lake Mohave	1980	3A	130
	1 mile north Ft. Mohave	1947	3B	405
	Needles, CA	1979	3B	172
	North end Lake Havasu	1966	3C	405
	Havasu Division	1974-76	3C	256
	San Bernardino County, CA	ND	3,4	18
	Moovalya Pond, Havasu Division	1974-75	4A	256
	Palo Verde Division	1974-76	4C	256
	Backwater A-7 Palo Verde Division	1972	4C	405
	Adobe Ruins Cibola/Imperial	ND	4C	18
	Imperial Division Lakes	1961	4C	20
	Martinez L.			
	Mittry L.			
	No Name 1			
	No Name 2			
	Imperial Dam Reservoir			
	Martinez L.	1969	4C	405
	Meers Pt. - Imperial NWR	1970	4C	405
	Laguna Division	1974-76	5A	256
	Bard, CA - Yuma Division	1944	5B	405

Species	Location	Year	Region	Reference
	Limitrophe Division	1974-76	5C	256
	Hunter's Hole, Limitrophe Division	1974	5C	258
	Lower Colorado River	1974-76	3,4,5	256
	Channel			
	Canals and drains			
Scirpus olneyi	Grand Canyon	1975	1B	203
	Grand Canyon	1976	1B	70
	Grand Canyon		1B	
	ORM 5.6	1980		140
	ORM 50.0	1980		140
	ORM 88.7	1980		140
	Pipe Creek (RM 601.3)	1945		405
	Pipe Creek (RM 601.3)	1977-78		72
	ORM 116.5	1980		140
	ORM 143.5	1980		140
	ORM 156 - Wupatquassee Creek	1973		405
	Havasu Canyon	1976		70
	ORM 156.5	1980		140
	ORM 179.0	1980		140
	Lava Falls Spring (RM 510.6)	1977-78		72
	Three Springs Canyon (RM 474.4)	1977-78		72
	ORM 216	1971		405
	Las Vegas Wash, Lake Mead	1979	2	172
	Lake Mead Wash, Lake Mead	1979	2	172
	Topock Gorge Division	1974-76	3B	256
	Havasu Division	1974-76	3C	256
	Riverside County, CA	ND	4B,C	18
	Backwater A-7, Palo Verde Division	1972	4C	405
	Imperial Division Lakes	1961	4C	20
	Martinez L.			
	Mittry L.			
	No Name 1			
	No Name 2			
	Imperial Reservoir Lake			
	Laguna Division	1974-76	5A	256
	Yuma to Limitrophe	ND	5B,C	18
	Limitrophe Division	1974-76	5C	256
	Lower Colorado River	1974-76	3,4,5	256
	Canals and drains			
	Channel			

Species	Location	Year	Region	Reference
Scirpus paludosus	Grand Canyon		1B	
	Little Colorado River (RM 627.4)	1977-78		72
	ORM 188 Whitmore Rapids	1970		405
	Ft. Mohave	1940	3B	405
	Imperial Damsite	1945	4C	405
	Bard, CA - Yuma Division	1943	5B	405
	Irrigation ditch, Yuma	1912	5B	405
Scirpus validus	ORM 52.5 Nankoweap Canyon	1974	1B	405
	Topock Marsh	1968	3B	146
	Havasu National Wildlife Refuge	1976	3C	227
	Imperial Division - Martinez L.	1945	4C	405
	1 mile below Imperial Dam	1974	5A	405
Scirpus sp.	Lake Mead	1980	2	232
	Hoover Dam to Willow Beach	1941	3A	259
	Mohave Valley	1974-76	3B	256
	Topock	1968	3B	145
	Topock Gorge	1965	3B	208
	Topock Gorge	1976	3B	227
	Topock Marsh	1980	3B	104
	Topock Gorge Division	1974-76	3B	256
	Bill Williams Arm - Lake Havasu	1980	3C	104
	Parker Division	1964	4A,B	389
	Parker Division	1967	4A,B	13
	Palo Verde Division	1974-76	4C	256
	Cibola Division	1974-76	4C	256
	Pilot Cut and Palo Verde Outfall, Cibola NWR	1980	4C	104
	Imperial Reservoir Lakes	1971	4C	417
	Imperial Division backwaters	1971	4C	226
	Draper L.			
	Velian L.			
	Taylor L.			
	#4			
	#5			
	#6			
	Devil L.			

Species	Location	Year	Region	Reference
	Ferguson L.			
	#9			
	#10			
	#12			
	Senator L.			
	#15			
	Squaw L.			
	Imperial Division backwaters	1975	4C	305
	Velian L.			
	Taylor L.			
	#4			
	#5			
	#6			
	Ferguson			
	#9			
	#10			
	#11			
	#12			
	Senator L.			
	#15			
	Squaw L.			
	Imperial Division	1974-76	4C	256
	Yuma Division	1974-76	5B	256
	Low and middle Limitrophe	1976	5C	35
	Hunter's Hole, Limitrophe Division	1975	5C	305
JUNCACEAE				
Juncus acutus	Grand Canyon	1975	1B	203
	Grand Canyon	1976	1B	70
	Grand Canyon		1B	
	ORM 95.0	1980		140
	RM 474.4 - 464.4	1977-78		72
	Travertine Falls (RM 459.7)	1977-78		72
	Davis Dam	1967	3B	405
	Backwater A-7 Palo Verde Division	1972	4C	405
	Imperial National Wildlife Refuge	1958	4C	405

Species	Location	Year	Region	Reference
Juncus articulatus	Grand Canyon	1977-78	1B	72
	RM 688.6 - 604.9			
	Paria River (RM 688.4)			
	Vasey's Paradise (RM 658.1)			
	Pipe Creek (RM 600.2)			
	RM 580.7 - 557.7			
	Tapeats Creek (RM 555.8)			
Juncus balticus	Above Lee Ferry	1980	1A	232
(var. montanus)	Grand Canyon		1B	
	Paria River (RM 688.4)	1977-78		72
	ORM 7.6	1980		140
	10 miles below Lee Ferry	1971		405
	Vasey's Paradise (RM 658.1)	1977-78		72
	ORM 32.0	1980		140
	ORM 34.0	1980		140
Juncus bufonius	Lake Mead	1977	2	107
	Willow Beach	1979	3A	172
	8 miles North Imperial Dam	1941	4C	405
	Imperial Lake	1941	4C	405
	Laguna Dam	ND	5A	405
Juncus cooperi	Lake Mead	1977	2	107
Juncus mexicanus	Grand Canyon		1B	
	ORM 32.0	1980		140
	ORM 34.0	1980		140
	Buck Farm (RM 647.9)	1977-78		72
	ORM 50.0	1980		140
	RM 627.4 - 604.9	1977-78		72
Juncus saximontanus	Grand Canyon	1975	1B	203
	Grand Canyon	1976	1B	70

Species	Location	Year	Region	Reference
	Grand Canyon		1B	
	ORM 4.3	1980		140
	ORM 5.6	1980		140
	ORM 7.6	1980		140
	ORM 19.0	1980		140
	ORM 32.0	1980		140
	ORM 34.0	1980		140
	ORM 37.8	1980		140
	ORM 46.0	1980		140
	ORM 61.5	1980		140
	ORM 87.6	1980		140
	Bright Angel at Roaring Springs	1976		70
	Phantom Ranch	1939		405
	ORM 87.8	1980		140
	Tapeats Creek (RM 555.8)	1977-78		72
Juncus torreyi	Grand Canyon	1975	1B	203
	RM 688.6 - 647.9	1977-78		72
	Vasey's Paradise (RM 658.1)	1977-78		72
	Clear Creek (RM 658.1)	1977-78		72
	ORM 87	1976		70
	ORM 87.6	1980		140
	Crystal Creek (RM 590.5)	1977-78		72
	Elves Chasm (RM 572.8)	1977-78		72
	Tapeats Creek (RM 555.8)	1977-78		72
	Kanab Creek (RM 546.1)	1977-78		72
	Separation Canyon (RM 450.6)	1939		405
	Separation Canyon (RM 450.6)	1980		140
	Lake Mead	1977	2	107
	Lake Mead	1980	2	232
	Ft. Mohave	1940	3B	405
	Topock	1946	3B	405
	Imperial Division - Ferguson L. entrance	1946	4C	405

Species	Location	Year	Region	Reference
Juncus xiphoides	Grand Canyon		1B	
	ORM 52.4	1976		70
	ORM 52.4	1980		140
Juncus sp.	Parker Division	1967	4A,B	13
	Deer Island Lake	1971	4B	15
SALICACEAE				
Populus fremontii	Grand Canyon		1B	
	Paria River (RM 688.4)	1977-78		72
	RM 647.9 - 627.4	1977-78		72
	ORM 40	1976		70
	Clear Creek (RM 604.9)	1977-78		72
	Bright Angel Creek (RM 601.3)	1977-78		72
	ORM 124.3	1976		70
	ORM 134.0	1976		70
	ORM 136.6	1976		70
	Kanab Creek	1977-78		72
	ORM 148.3	1976		70
	Havasu Creek	1976		70
	Supai Village	1941		405
	ORM 167.5	1976		70
	ORM 171.0	1976		70
	Grand Canyon	1980	1B	140
	Grand Canyon - Lee to Pierce Ferry	1980	1B	386
	Lake Mead	1954	2	193
	Lake Mead	1977	2	107
	Lake Mead	1970	2	314
	Lake Mead	1979	2	172
	Willow Beach	1979	3A	237
	Lake Mohave	1954	3A	193
	Lake Mohave	1978	3A	314
	Below Davis Dam	1954	3B	193
	Lower Colorado River - isolated stands from Davis Dam to Mexico	1974-76	3,4,5	256

Species	Location	Year	Region	Reference
	Needles	1915	3B	405
	Parker	1913	4B	405
	Imperial Division	1971	4C	226
	Imperial Division	1975	4C	305
	Yuma Valley, Colorado River	1912	5B	405
	Yuma	1912	5B	405
	Yuma	1913	5B	405
	Floodplain Colorado River, Yuma	1916	5B	405
Salix exigua	Above Lee Ferry	1980	1A	232
	Grand Canyon		1B	
	RM 688.8 - 450.6	1977-78		72
	Paria River (RM 688.4)	1977-78		72
	ORM 11.2	1976		70
	Vasey's Paradise (RM 658.1)	1977-78		72
	ORM 32	1976		70
	Buck Farm (RM 647.9)	1977-78		72
	Nankoweap (ORM 52.5)	ND		405
	ORM 52.4	1976		70
	Little Colorado River (RM 627.4)	1977-78		72
	Cardinas Creek (ORM 71.2)	ND		405
	Bright Angel Creek (RM 601.3)	1916		405
	Bright Angel Creek (RM 601.3)	1937		405
	Phantom Ranch	1940		405
	ORM 87.0	1976		70
	Pipe Creek (RM 600.2)	1977-78		72
	Hermit Trail	1976		70
	Shinumo Creek (RM 580.7)	1977-78		72
	Elves Chasm (RM 572.8)	1977-78		72
	ORM 122.4	1976		70
	ORM 122.5	1974		405
	Tapeats Creek (RM 555.8)	1977-78		72
	Tapeats Creek (RM 555.8)	ND		405
	ORM 136.2	1976		70
	Deer Creek (ORM 135.9)	1976		405
	Havasu Canyon (RM 533.0)	1976		70
	Havasupai	1939		405
	Havasupai	1940		405

Species	Location	Year	Region	Reference
	Havasupai	1941		405
	Lava Falls Spring (ORM 179)	1976		70
	ORM 192	1976		70
	Three Springs Canyon (RM 474.4)	1980		406
	Surprise Canyon ORM 248	ND	1B	405
	Grand Canyon	1980	1B	140
	Lake Mead	1977	2	107
	Lake Mead National Recreation Area	1979	2	172
	Lower Colorado River	ND	3,4,5	18
	Lower Colorado River - Davis Dam to Mexico isolated stands	1974-76	3,4,5	256
	San Bernadino County, CA	ND	3,4	18
	Cottonwood Spring	1978	3	405
	Backwater A-7, Palo Verde Division	1972	4C	405
	Imperial Dam	1974	4C	405
	1 mile below Imperial Dam	1974	4C	405
	Yuma sand bars	1912	5B	405
	Colorado River floodplain, Yuma	1916	5B	405
Salix gooddingii	Grand Canyon		1B	
	ORM 32	1976		70
	ORM 40	1976		70
	ORM 71	1976		70
	ORM 87	1976		70
	RM 580.7 - 546.1	1977-78		72
	Havasu Creek (RM 533.0)	1977-78		72
	Havasu Canyon	1976		70
	RM 508.6 - 450.6	1977-78		72
	ORM 192	1976		70
	ORM 195.2	1976		70
	ORM 200.7	1976		70
	ORM 209.0	1976		70
	Grand Canyon - various miles	1980	1B	140
	Grand Canyon - Lee to Pierce Ferry	1980	1B	386
	Lake Mead	1977	2	107
	Lake Mead National Recreation Area	1979	2	124

Species	Location	Year	Region	Reference
	Lake Mohave - 4 miles south Cottonwood Cove	1979	3A	172
	Lower Colorado River	ND	3,4,5	18
	Lower Colorado River - Davis Dam to Mexico isolated stands	1974-76	3,4,5	256
	Yuma County	ND	4,5	18
Salix laevigata	Grand Canyon		1B	
	Bright Angel Trail	1976		70
	Kaibab Trail	1976		70
	ORM 134.0	1976		70
	Havasu Canyon	1940-41		405
	Havasu Creek	1946		406
	Havasu Canyon	1976		70
	Havasu Canyon (RM 533.0)	1977-78		72
	RM 508.6 - 474.4	1977-78		70
	ORM 209	1976		70
Salix lasiolepis	Grand Canyon		1B	
	Havasu Canyon	1976		70
	ORM 84.0	1980		140
	ORM 87.0	1980		140
	ORM 89.0	1980		140
Salix vallicola	Grand Canyon		1B	
	ORM 71.2	1972		405
	Phantom Ranch	1945		405
	Supai	1941		405
	ORM 194.8	1972		405
	ORM 209 Granite Park	1974		405
	Lake Mean - Columbine Falls	1972		405
	Columbine Falls	1975		405
	Willow Beach	1938	3A	405
	Willow Beach	1942	3A	405
	Holiday Shores	1916	3B	405
	Imperial Dam	1974	4C	405
	Bard, CA	1912	5B	405
	Yuma Valley - commonest willow	1912	5B	405
	Yuma	1915	5B	405
	Floodplain Colorado River, Yuma	1916	5B	405

Species	Location	Year	Region	Reference
TAMARICACEAE				
Tamarix aphylla	Grand Canyon	1980	1B	140
	ORM 260			
	ORM 270			
	Lake Mead - Rampart Cave	ND	2	405
	Topock	1960	3B	405
	½ mile east Martinez Village Martinez Lake	1974	4C	405
Tamarix chinensis	Grand Canyon		1B	
	Lee Ferry	1976		70
	ORM 28.7	1976		70
	ORM 32.0	1976		70
	ORM 40.1	1976		70
	ORM 46.8	1976		70
	ORM 93.3	1976		70
	ORM 136.2	1976		70
	Havasu Canyon (ORM 156)	1976		70
	ORM 209	1976		70
	ORM 209 Granite Park	ND		18
	ORM 280	1976		70
	Grand Canyon Glen Canyon Dam to Pierce Ferry	1980	1B	386
	Yuma County	ND	4,5	18
Tamarix gallica	Lee Ferry	1935	1B	405
	Lake Mohave	1954	3A	193
	Lake Havasu	1954	3C	42
Tamarix pentandra	Grand Canyon	1977-78	1B	72
	RM 688.8 - 450.6			
	Paria River (RM 688.4)			
	Vasey's Paradise (RM 658.1)			
	Nankoweap (RM 636.4)			
	Little Colorado River (RM 627.4)			
	Clear Creek (RM 604.9)			
	Pipe Creek (RM 600.2)			

Species	Location	Year	Region	Reference
	Hermit Creek (RM 594.4)			
	Crystal Creek (RM 590.8)			
	Shinumo Creek (RM 580.7)			
	Elves Chasm (RM 572.8)			
	Stone Creek (RM 557.7)			
	Deer Creek (RM 553.2)			
	Havasu Creek (RM 533.0)			
	Three Springs Canyon (RM 474.4)			
	Diamond Creek (RM 464.4)			
	Travertine Falls (RM 459.7)			
	Grand Canyon ORM 0.1 - 280.0	1980	1B	140
	Grand Canyon National Park	1980	1B	406
	1 mile up from Pierce Ferry	1969	2	405
	Pierce Ferry	1972	2	405
	Davis Dam to Holiday Shores	1969	3B	405
	Bullhead City	1965	3B	405
	Imperial National Wildlife Refuge - Meers Pt.	1970	4C	405
	Yuma Crossing	1953	5B	405
	Yuma - Limitrophe	ND	5B,C	18
Tamarix sp.	Lake Mead	1954	2	193
	Lake Mead	1977	2	107
	Lake Mead	1978	2	314
	Lake Mead	1980	2	232
	Lake Mead National Recreation Area	1979	2	172
	Lake Mohave	1954	3A	193
	Lake Mohave	1978	3A	314
	Below Davis Dam	1954	3B	193
	Lower Colorado River, Davis Dam to Mexico	1974-76	3,4,5	256
	Topock Marsh	1968	3B	146
	Imperial Division Backwaters	1971	4C	226
	Imperial Division Backwaters	1975	4C	305
COMPOSITAE				
Baccharis emoryi	Havasu Canyon, Navajo Falls	1948	1B	406
	Grand Canyon ORM 18.8 - 274	1976	1B	70
	Grand Canyon - RM 604.9 - 580.7	1977-78	1B	72
	Bright Angel Creek (RM 601.3)			

Species	Location	Year	Region	Reference
	Pipe Creek (RM 600.2)			
	Hermit Creek (RM 594.4)			
	Crystal Creek (RM 590.8)			
	Grand Canyon - Shores and glens	1979	1B	172
	Grand Canyon ORM -9.0 - 280.0	1980	1B	140
	Grand Canyon - Lee to Pierce Ferry	1980	1B	386
	Grand Canyon ORM 219	1980	1B	406
	Lake Mead 3 miles south Temple Bar	1979	2	172
Baccharis glutinosa	Grand Canyon - Emory Falls	1939	1B	406
	Grand Canyon ORM 0.0 - 209.5	1976	1B	70
	Grand Canyon - Lee Ferry	1978	1B	406
	Hance Rapids	1978		406
	Grand Canyon ORM 0.1 to 280.0	1980	1B	140
	Grand Canyon Lee to Pierce Ferry	1980	1B	386
	Grand Canyon ORM 219	1980	1B	406
	Lake Mead National Recreation Area	1979	2	172
	Limitrophe Division	ND	5C	18
Baccharis salicifolia	Grand Canyon	1977-78	1B	72
	RM 688.8 - 658.1			
	RM 647.9 - 627.4			
	Clear Creek (RM 604.9)			
	Bright Angel Creek (RM 601.3)			
	Pipe Creek (RM 600.2)			
	Hermit Creek (RM 594.4)			
	Crystal Creek (RM 590.8)			
	Elves Chasm (RM 572.8)			
	RM 557.7 - 546.1			
	Tapeats Creek (RM 555.8)			
	Deer Creek (RM 553.2)			
	Havasu Creek (RM 533.0)			
	Three Springs Canyon (RM 474.4)			
	219 Mile Canyon (RM 470.8)			
	Mile 220 (RM 468.6)			

Species	Location	Year	Region	Reference
	Lower Colorado River Davis Dam to Mexico	1974-76	3,4,5	256
Baccharis sarothroides	Grand Canyon		1B	
	ORM 40	1980		140
	ORM 40.3	1980		140
	ORM 41.0	1980		140
	ORM 165	1976		70
	ORM 165	1980		140
	ORM 166.5	1980		140
	ORM 167.5	1976		70
	ORM 167.5	1980		140
	ORM 179.0	1976		70
	ORM 179.0	1980		140
	ORM 205.0	1979		172
	ORM 205.0	1980		140
	ORM 209.0	1976		70
	ORM 209.0	1980		140
	Tucker to Peach Springs Canyon	1980	1B	386
	Lower Colorado River Davis Dam to Mexico	1974-76	3,4,5	256
Baccharis sergiloides	Grand Canyon		1B	
	ORM 28.7	1976		70
	ORM 28.7	1980		140
	ORM 39.0	1980		140
	ORM 84.0	1980		140
	Shinumo Cr. to Tatahatso Creek	1980		386
	ORM 124.0	1980		140
	Tapeats Creek to Tucker Canyon	1980		386
	ORM 174.5	1980		140
	ORM 219	1980		406
	ORM 271	1980		140
	ORM 272	1980		140
	ORM 280	1980		140
	Lake Mead	1977	2	107
	Lake Mead	1979	2	172
	Adobe Ruins - Cibola/Imperial Divisions	ND	4C	18

Species	Location	Year	Region	Reference
Baccharis viminea	Lower Colorado River Davis Dam to Mexico	1974-76	3,4,5	256
	Lower Colorado River	ND	3,4,5	18
	Yuma County	ND	4,5	18
	Limitrophe Division	ND	5C	18
Pluchea camphorata	Lower Colorado River	1974-76	3,4,5	256
Pluchea purpurescens	Grand Canyon ORM 275.0	1976	1B	140
	Lower Colorado River	1974-76	3,4,5	256
Tessaria sericea	Grand Canyon - Havasu Canyon	1948	1B	406
	Grand Canyon - Buck Farm Canyon	1974	1B	406
	Grand Canyon - Lee Ferry to ORM 275.0	1976	1B	70
	Grand Canyon	1977-78	1B	72
	RM 688.8 - 647.9			
	Paria River (RM 688.6)			
	RM 604.9 - 450.6			
	Stone Creek (RM 557.7)			
	Deer Creek (RM 553.2)			
	Kanab Creek (RM 546.1)			
	Lava Falls Spring (RM 510.6)			
	Grand Canyon ORM 0.1 to 280.0	1980	1B	140
	Grand Canyon Lee to Pierce Ferry	1980	1B	386
	Lake Mead	1954	2	193
	Lake Mead	1978	2	314
	Lake Mead National Recreation Area	1979	2	172
	Pierce Ferry			
	Lake Mead mud flats			
	Below Hoover Dam		3A	
	Lake Mohave	1954	3A	193
	Lake Mohave	1978	3A	314
	Below Davis Dam	1954	3B	193
	Lower Colorado River - Davis Dam to Mexico	1974-76	3,4,5	7256
	San Bernadino County, CA	ND	3,4	18
	Topock Marsh	1968	3B	146
	Lake Havasu	1954	3C	42
	Riverside County, CA	ND	4B,C	18
	Deer Island Lake - Parker Division	1971	4B	15
	Adobe Ruins - Cibola/Imperial Divisions	ND	4C	18
	Yuma to Limitrophe Division	ND	5B,C	18

Appendix 6. Vascular Plants with Aquatic Affinities Reported from the Vicinity of the Colorado River.

EQUISETACEAE

Equisetum arvense
E. hyemale
E. laevigatum

POLYPODIACEAE

Adiantum capillis-veneris

TYPHACEAE

Typha angustifolia
T. domingensis
T. latifolia

SPARGANIACEAE

Sparganium emersum

ALISMATACEAE

Alisma triviale
Sagittaria cuneata

GRAMINEAE (POACEAE)

Agropyron smithii
A. subsecundum
A. trachycundum
Agrostis alba
A. exarata
A. idahoensis
A. scabra
A. semiverticillata
A. stolonifera var. *palustris*
Alopecurus aequalis
A. geniculatus
Andropogon glomeratus
Arundo donax
Beckmannia syzigachne
Bromus catharticus
B. japonicus
B. marginatus
B. richardsonii
Calamogrostis canadensis

C. inexpansa
Cynodon dactylon
Dactylis glomerata
Danthonia intermedia
Deschampsia caespitosa
Digitaria sanguinalis
Distichlis spicata var. *stricta*
Echinochloa crusgalli
Elymus canadensis
E. triticoides
Eragrostis cilianensis
E. pectinacea
Erianthus ravennae
Festuca arizonica
Glyceria borealis
G. stricta
Hierochloe odorata
Hordeum brachyantherum
H. jubatum
Leptochloa uninervis
Lolium multiflorum
L. perenne
Muhlenbergia asperifolia
M. curtifolia
M. filiformis
M. microsperma
M. minutissima
M. racemosa
M. richardsonis
M. sylvatica
Panicum bulbosum
P. capillare
P. huachucae
P. obtusum
P. virgatum
Paspalum dilatatum
Phalaris arundinaceae
Phleum alpinum
P. pratense
Phragmites australis
Poa annua
P. compressa
P. interior
P. pratensis
P. reflexa
Polypogon interruptus
P. monspeliensis
Setaria glauca
S. verticillata

Sorghum halepense
Sphenopholis obtusata
Sporobolus flexuosus
S. texanus

CYPERACEAE

Carex albonigra
C. aquatilis
C. athrostachya
C. canescens
C. curatorum
C. douglasii
C. hassei
C. haydeniana
C. hystricina
C. languinosa
C. microptera
C. nebraskensis
C. praegracilis
C. rostrata
C. scoparia
C. senta
C. thurberi
Cladium californicum
C. mariscus var. _californicum_
Cyperus aristatus
C. erythronhizos
C. esculentus
C. strigosus
Eleocharis acicularis
E. bella
E. caribea
E. macrostachya
E. montividensis
E. parishii
E. parvula
E. radicans
E. rostellata
Fimbristylus thermalis
Scirpus acutus
S. americanus
S. californicus
S. maritimus var. _paludosus_
S. olneyi
S. paludosus
S. robustus
S. validus

LEMNACEAE

Lemna minima

JUNCACEAE

Juncus acutus
J. articulatus
J. badius
J. balticus
J. bufonius
J. confusus
J. cooperi
J. interior
J. longistylus
J. mertensianus
J. mexicanus
J. saximontanus
J. tenuis
J. torreyi
J. tracyi
J. xiphoides

LILIACEAE

Smilacina stellata
Veratrum californicum
Zigadenus elegans

IRIDACEAE

Sisyrinchium demissum

ORCHIDACEAE

Epipactis gigantea
Habenaria sparsiflora
Spiranthes romanzoffiana

SAURURACEAE

Anemopsis californica

SALICACEAE

Populus angustifolia
P. fremontii
Salix bebbiana
S. bonplandiana
S. exigua
S. geyeriana

S. gooddingii
S. laevigata
S. lasiandra
S. lasiolepis
S. lutea
S. scouleriana
S. vallicola

JUGLANDACEAE

Carya illinoinensis
Juglans major

BETULACEAE

Alnus oblongifolia
A. tenuifolia
Betula occidentalis

ULMACEAE

Celtis reticulata

URTICACEAE

Parietaria floridana
P. pennsylvanica
Urtica serra

POLYGONACEAE

Oxyria digyna
Polygonum amphibium
P. argyrocoleon
P aviculare
P. bistortoides
P. coccineum
P. fusiforme
P. kelloggii
P. persicaria
P. punctatum
Rumex acetosella
R. altissimus
R. californicus
R. conglomeratus
R. crispus
R. mexicanus

CHENOPODIACEAE

Alenrolfia occidentalis
Atriplex argentea
A. lentiformis
Bassia hyssopifolia
Chenopodium album
C. fremontii
Salisola kali
Suaeda torreyana

AMARANTHACEAE

Amaranthus graecizans

AIZOACEAE

Sesuvium verrucosum
Trianthema portulacastrum

PORTULACACEAE

Montia perfoliata

CARYOPHYLLACEAE

Cerastium arvense
C. nutans
Sagina saginoides var. _hesperia_

RANUNCULACEAE

Aconitum columbianum
Aquilegia chrysantha
Caltha leptosepala
Clematis ligusticifolia
Myosurus cupulatus
M. minimus
Ranunculus aqualilis var. _capillaceus_
R. cymbalaria var. _saximontanus_
R. flammula var. _ovalis_
R. scleratus
Thalictrum fendleri

CRUCIFERAE

Capsella bursa-pastoris
Draba cuneifolia
Rorippa curvisiliqua
R. islandica
R. nasturtium-aquaticum
R. obtusa
R. sphaerocarpa

R. sylvestris
Thelypodium integrifolium

CLEOMACEAE

Cleome lutea

SAXIFRAGACEAE

Parnassia parviflora
Ribes inerme
R. wolfi

ROSACEAE

Potentilla biennis
P. diversifolia
P. glandulosa
P. norvegica
P. rivalis
Rosa arizonica

LEGUMINOSAE

Acacia greggii
Alhaga camelorum
Amorpha californica
Astragalus praelongus
A. sabulonum
Cercis occidentalis
Glycerrhiza lepidota
Prosopis glanulosa
P. juliflora
P pubescens
P. velutina
Sesbania macrocarpa
Trifolium hybridum
T. pinetorum
T. pratense
T. repens

CALLITRICHACEAE

Callitriche verna

ACERACEAE

Acer negrundo

RHAMNACEAE

Rhamnus betulaefolia

VITACEAE

Vitis arizonica

MALVACEAE

Iliamna grandiflora
Sida hederacea
Sidalcea neomexicana

ELATINACEAE

Elatine brachysperma
E. triandra

TAMARICACEAE

Tamarix aphylla
T. chinensis
T. gallica
T. pentandra

LYTHRACEAE

Lythrum californicum

ONAGRACEAE

Epilobium adenocaulon
E. halleanum
E. saximontanum
Oenothera flava
O. hookeri
O. longissima

UMBELLIFERAE

Apium gravelolens
Berula erecta
Caucalis microcarpa
Cicuta douglasii
Conium maculatum
Hydrocotyl verticillata
Perideridia parishii

CORNACEAE

Cornus stolonifera

PRIMULACEAE

Androsace occidentalis
A. serpentrionalis

Dodecatheon alpinum
Samolus parviflorus

OLEACEAE

Fraxinus pennsylvanica

GENTIANACEAE

Centarium calycosum
Eustoma exaltatum

APOCYNACEAE

Apocynum cannabinum
A. sibiricum

ASCLEPIADACEAE

Sarcostemma cyanchoides

HYDROPHYLLACEAE

Phacelia filiformis
P. glechomaefolia
P. laxiflora
P. magellanica

BORAGINACEAE

Heliotropium curassavicum

VERBENACEAE

Phyla incisa
Verbena bractea
V. macdougalii

LABIATAE

Mentha arvenis var. *villosa*
M. spicata
Prunella vulgaris

SOLANACEAE

Nicotania glauca

SCROPHULARIACEAE

Bacopa monneri
Mimulus cardinalis

M. eastwoodii
M. guttatus
M. nasutus
M. rubellus
Veronica americana
V. anagallis-aquatica
V. serphyllifolia var. borealis

BIGNONIACEAE

Chilopsis linearis

PLANTAGINACEAE

Plantago lanceolata
P. major
P. virginica

RUBIACEAE

Galium aparina
G. triflorum

CAMPANULACEAE

Lobelia cardinalis

COMPOSITAE

Ambrosia psilostachya
Aster intricatus
A. spinosus
Baccharis emoryi
B. glutinosa
B. viminea
Bacopa monnieri
Flaveria mcdougallii
Gnaphalium chilense
G. exilifolium
G palustre
Oxytenia acerosa
Solidaga elongata
S. occidentalis
Tessaria serecia
Xanthium strumarium

Appendix 7. Distribution of Aquatic Invertebrates in the Colorado River

Species	Location	Region	Reference
PORIFERA			
Spongillidae	Cottonwood Cove, Lake Mohave	3A	55
COELENTERATA			
Craspedacusta sowerbii	Lake Mead, 1954 and 1962	2	314
Hydriadae	Cottonwood Cove, Lake Mohave	3A	55
Pelmatohydra oligactis	Lake Mead	2	314
Hydra sp.	Colorado River in Grand Canyon	1B	86
	Colorado River Indian Reservation	4B	104
PLATYHELMINTHES			
Turbellaria	Elves Chasm RM 572.8	1B	72
	Mohave Valley ORM 422.0-429.9		256
	backwaters ORM 422-464.0	3B	256
	Parker Division ORM 540-549.9	4B	256
	Deer Island Lake RM 172	4B	323
NEMATODA			
Contracaecum multipapellatum	Lake Mead	2	314
	Lake Mohave	3A	314
Nematoda sp.	Vasey's Paradise RM 658.1	1B	86
	Lake Mead	2	193
	Deer Island L. RM 172	4B	323
MOLLUSCA			
Gastropoda	Glen Canyon Dam to Lee Ferry	1A	365
	Glen Canyon Dam to Lee Ferry	1A	364
	Lake Mead	2	241
	Lake Mead	2	232
	Lake Mohave	3A	130
	Topock Gorge backwaters	3B	227
	Parker Dam to Morelos Dam	4,5	159

Species	Location	Region	Reference
	2 miles up to 1 miles down from Agnes Wilson Bridge, Parker Division	4B	391
	Imperial Reservoir Lakes	4C	417
	Imperial Division lakes	4C	417
Lymnaeidae	Lee Ferry - introduced 1965	1A	72
	Vasey's Paradise RM 658.1	1B	72
	Elves Chasm RM 572.8	1B	72
	ORM 422-464 Backwaters (Mohave Valley)	3B	256
Lymnaea sp	Lake Mead	2	314
	Lake Mohave	3A	193
	Lake Mohave	3A	314
	below Davis Dam	3B	193
Lymnaea stagnalis	10th Avenue backwater, sec. 36	4C	304
Radix sp.	ORM 422-429.9 (Mohave Valley)	3B	256
	ORM 524.9-529.9 (Parker Division)	4B	256
	ORM 540.0-549.9 (Parker Division)	4B	256
	Moovalya Lake, (Havasu Division)	4A	256
Radix auricularia	ORM 422-464 (Mohave Valley backwaters)	3B	256
Physidae	Lee Ferry - introduced 1965	1A	72
	Mainstem Colorado River, Grand Canyon	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Hermit Creek RM 594.4	1B	72
	Elves Chasm RM 572.8	1B	72
	Deer Creek RM 553.2	1B	72
	Havasu Creek RM 533.0	1B	72
	Lava Falls Spring RM 510.6	1B	72
	Three Springs Canyon RM 474.4	1B	72
	Bridge Canyon RM 455.1	1B	72
	Imperial Dam backwaters	4C	226
	Devil L.		
	Ferguson L.		
	No Name 9		
	No Name 12		

Species	Location	Region	Reference
Physa sp.	Lake Mead	2	314
	Lake Mead	2	232
	Lake Mohave	3A	314
	Deer Island Lake RM 172	4B	320
	Imperial Reservoir	4C	152
Physa gyrina	10th Avenue backwater sec. 36	4C	304
	ORM 650-657.2 Imperial backwaters	4C	256
	ORM 690-699.9 Limitrophe backwaters	5C	256
	ORM 700-704.2 Limitrophe backwaters	5C	256
Physa virgata	Bright Angel Creek RM 601.3	1B	45
	ORM 422-429.9 Mohave Valley Division	3B	256
	ORM 540-549.9 Parker Division	4B	256
	ORM 570-579.9 Palo Verde Division	4C	256
	ORM 680-683.7 Yuma Division	5B	256
	ORM 700-704.2 Limitrophe Division	5C	256
Planorbidae			
Gyraulus parvus	ORM 464-469.9 Mohave Valley Division	3B	256
Pelecypoda			
Anodonta californensis	Yuma	5B	45
Corbicula maniliensis (also *C. fluminea*)	Lake Mead (since 1962)	2	314
	Lake Mead	2	232
	Las Vegas Bay, Lake Mead	2	241
	Temple Bar, Lake Mead	2	45
	Lake Mohave	3A	314
	Lake Mohave	3A	130
	Cottonwood Cove, Lake Mohave	3A	55
	Davis Dam to Mexican Boundary, mainstem and tributaries	3,4,5	256
	Topock Gorge backwaters	3B	227
	Backwater 1, 2 miles south I-40 bridge	3C	227
	Lake Havasu	3C	392
	Lake Havasu	3C	220
	Lake Havasu	3C	396
	Moovalya Lake, Havasu Division	3C	256
	Parker Dam to Morelos Dam	4,5	159
	Parker Dam to Parker	4A	396
	4 miles SW Parker	4B	45

Species	Location	Region	Reference
	Parker Division	4A, 4B	391
	2 miles up, 1 mile down from Agnes Wilson Bridge	4B	391
	Colorado River Indian Reservation	4B, 4C	396
	Palo Verde Irrigation District canals and drains	4B, 4C	396
	P.V.I.D.	4B, 4C	162
	P.V.I.D.	4B, 4C	163
	10th Avenue backwater sec. 36	4C	304
	Imperial Reservoir	4C	152
	Martinez Lake, Imperial Division	4C	45
	Imperial Backwater Lakes		
	Taylor Lake	4C	226
	Taylor Lake	4C	303
	Taylor Lake	4C	305
	Unnamed 4	4C	226
	Unnamed 4	4C	305
	Unnamed 5	4C	226
	Unnamed 6	4C	226
	Devil Lake	4C	226
	Ferguson Lake	4C	226
	Unnamed 9	4C	226
	Unnamed 11	4C	226
	Unnamed 12	4C	226
	Senator Lake	4C	226
	Squaw Lake	4C	226
	Imperial Dam to Laguna Dam	5A	396
	Yuma	5B	45
	Hunter's Hole, Limitrophe Division	5C	258
Pisidium sp.	ORM 470-478, Topock Gorge backwaters	3B	256
Sphaeridae	RM 23.2; 34.5; 44.0; 50.0 101.5 (canals, drains and river) 139.6 (Col. R. Ind. Res. Canal) 196.0; 200.6.	4,5	396
Sphaerium sp.	Imperial Dam pond	5A	207
Sphaerium simile	Yuma before 1912	5B	45

Species	Location	Region	Reference
ANNELIDA			
Hirudinea	Lee Ferry - introduced 1965	1A	72
	Glen Canyon to Lee Ferry	1A	365
	ORM 422-429.9 Mohave Valley	3B	256
	Moovalya Lake, Havasu Division	3C	256
	ORM 524.9-529.9 Parker Division	4B	256
	ORM 560-568.8 Parker Division	4B	256
	ORM 650-657.2 Imperial Division	4C	256
	ORM 700-704.2 Limitrophe backwaters	5C	256
Oligochaeta	Colorado River mainstem, Grand Canyon	1B	72
	Tributaries		
	Paria River RM 688.4	1B	72
	Vasey's Paradise RM 658.1	1B	86
	Little Colorado River RM 627.4	1B	72
	Little Colorado River RM 627.4	1B	86
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Bright Angel Creek RM 601.3	1B	86
	Pipe Creek RM 600.2	1B	72
	Hermit Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72
	Shinumo Creek RM 580.7	1B	72
	Shinumo Creek RM 580.7	1B	86
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Stone Creek RM 557.7	1B	72
	Tapeats Creek RM 555.8	1B	72
	Tapeats Creek RM 555.8	1B	86
	Deer Creek RM 553.2	1B	72
	Deer Creek RM 553.2	1B	86
	Kanab Creek RM 546.1	1B	72
	Kanab Creek RM 546.1	1B	86
	Havasu Canyon RM 533.0	1B	72
	National Canyon RM 523.3	1B	72

Species	Location	Region	Reference
ARTHROPODA			
Arachnida			
Sperchonidae	Grand Canyon	1B	72
Crustacea			
Ostracoda	Lake Havasu	3C	199
	Deer Island Lake, Parker Division RM 172	4B	323
	Imperial Division Lakes	4C	417
Cypridae	Colorado River Tributaries and mainstem	1B	72
	Bright Angel RM 601.3		
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Elves Chasm RM 572.8		
	Kanab Creek RM 546.1		
(Cypridae)			
Cyprinotus incongruens	Mainstem Colorado River	1B	86
	Havasu Creek RM 533.0	1B	86
C. pellucidus	Deer Creek RM 553.0	1B	86
C. salinus	Elves Chasm RM 572.8	1B	86
Paracandona euplectella	Mainstem Colorado River	1B	86
Potamocypris sp.	Elves Chasm RM 572.8	1B	86
Ilyocypris bradyii	Havasu Creek RM 533.0	1B	86
Herpetocypris reptans	Elves Chasm RM 572.8	1B	86
	Diamond Creek RM 464.4	1B	86
Cypridopsis vidua	Elves Chasm RM 572.8	1B	86
AMPHIPODA			
Gammarus fasciatus	Glen Canyon to Lee Ferry	1A	365
and _G. lacustris_	Mainstem Colorado River	1B	86
	Lee Ferry to Diamond Creek RM 688.6-464.4	1B	85
	Mainstem Colorado River and tributaries	1B	72
	introduced 1932 Bright Angel Creek		
	introduced 1965 Lee Ferry		
	Vasey's Paradise RM 658.1		
	Little Colorado River RM 627.4		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Crystal Creek RM 590.8		

Species	Location	Region	Reference
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	introduced below Hoover Dam 1941	3A	259
	Hoover to Willow Beach area	3A	314
	Willow Beach area reintroduced 1972	3A	314
	Lake Mohave area prior to dam	3A	193
	river below Davis Dam	3B	193
	Davis Dam	3B	127
	below Davis Dam	3B	127
	Lake Havasu	3C	42
DECAPODA			
Crayfish sp.	Lake Havasu	3C	199
	Parker Dam to Headgate Rock Dam	4A	199
	Blythe RM 120	4C	42
	Imperial Reservoir	4C	42
	Yuma Division	5B	42
	Hunter's Hole, Limitrophe Division	5C	252
Asticus sp.	Lake Mohave	3A	193
Cambarus sp.	introduced 1935 at Winterhaven	5B	101
	introduced 1941 at Picacho		101
	1942 populations to Laguna;	5	101
	common at Winterhaven	5B	101
	Haughtelin Lake	5B	101
Pacifistacus sp.	Lake Mead	2	206
Procambarus clarki	Lake Mead	2	314
	Lake Mead	2	232
	Lake Mohave	3A	314
	10th Avenue backwater, section 36	4C	304
Paleomonetes paludosus	Bright Angel Creek introduced	1B	16
	Colorado River below Davis Dam - local pop.	3,4,5	326
	Topock Marsh	3B	104
	Lake Havasu 1958 introduced	3C	326
	Havasu Landing 1958 introduced	3C	356
	Havasu Landing 1962 introduced	3C	104
	Havasu Landing 1963 introduced	3C	156
	Bill Williams Arm	3C	104

Species	Location	Region	Reference
	Marina Village, 7 miles above Headgate Rock Dam 1963 introduced	4A	157
	Branson's Resort 5.3 miles above Headgate Rock Dam 1963 introduced	4A	157
	Lost Lake Camp/Alligator Slough 1963 introduced	4B	157
	10th Avenue backwater Sec. 36	4C	304
	below Palo Verde Weir introduced 1963	4C	157
	Palo Verde Drain introduced 1963	4C	157
	Imperial Reservoir Lakes	4C	417
	Imperial Dam Pond	5A	207
ARTHROPODA - INSECTA			
COLLEMBOLA			
Entomobryidae	ORM .9 - 116.4	1B	71
Isotomidae	Buck Farm RM 647.9	1B	72
	Elves Chasm RM 572.0	1B	72
Isotoma sp.	mainstem Colorado River	1B	86
Poduridae	ORM 34.9 - 65.2	1B	71
Sminthuridae	ORM 34.9 - 246.0	1B	71
EPHEMEROPTERA	Lee Ferry 1965 introduced	1A	72
	Lake Mohave area prior to Davis Dam	3A	193
	ORM 422.0 - 429.9; 440.0 - 449.9 Mohave Valley Div.	3B	256
	Parker Dam to Parker	4A	396
	Parker Dam to Morelos Dam	4,5	159
	ORM 530 - 559.9, Parker Division	4B	256
	Moovalya L. Havasu Division	4A	256
	RM 176.5 Parker Division	4B	104
	Colorado River Indian Reservation	4B	104
	Palo Verde Irrigation System	4B,C	396
	Laguna Dam and below	5B,C	396

Species	Location	Region	Reference
Heptageniidae	ORM 31.9 - 133.8	1B	71
	Grand Canyon tributaries	1B	72
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Stone Creek RM 557.7		
	Tapeats Creek RM 555.8		
	National Canyon RM 523.3		
	ORM 422 - 429.9 Mohave Valley Division	3B	256
	ORM 524 - 529.9 Parker Division	4B	256
	2 miles up, 1 mile down from Agnes Wilson Bridge, Parker Division	4B	391
Cinygama sp.	RM 386.5	2	396
Iron sp.	Tapeats Creek RM 555.8	1B	86
Baetidae	Grand Canyon tributaries	1B	72
	Paria River RM 688.4		
	Vasey's Paradise RM 658.1		
	Buck Farm RM 647.9		
	Little Colorado River RM 627.4		
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Crystal Creek RM 590.8		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Stone Creek RM 557.7		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	Havasu Creek RM 533.0		
	National Canyon RM 523.3		
	219 Mile Canyon RM 470.8		
	Diamond Creek RM 464.4		

Species	Location	Region	Reference
	Travertine Canyon RM 459.7		
	Travertine Falls RM 459.7		
	Bridge Canyon RM 455.1		
	ORM 31.9 to 246	1B	71
	ORM 524 - 529.9 Parker Division	4B	256
	Hunter's Hole, Limitrophe Division	5C	258
Ameletus sp.	RM 21.3, 23.2, 28.0, 34.5, 44.0, 110.2, 196.0, 199.2	3,4,5	396
Baetis sp.	Grand Canyon tributaries	1B	86
	Vasey's Paradise RM 658.1		
	Bright Angel Creek RM 601.3		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	Havasu Creek RM 533.0		
	Diamond Creek RM 464.4		
	RM 199.2	3C	396
Callibaetis sp.	Elves Chasm RM 572.8	1B	86
	Hoover Dam to Davis Dam site	3A	259
Callibaetis californicus	10th Ave. backwater Sec. 36	4C	304
Ephemerella sp.	RM 110.2 - 386.5	4C,2	396
Isonychia sp.	RM 386.5	2	396
Tricorythodes sp.	Diamond Creek RM 464.4	1B	86
	RM 44.0, 101.5, 110.2, 199.2, 386.5	2,3,4,5	396
Caenidae (Baetidae?)	Diamond Creek RM 464.4	1B	72
Caenis sp.	RM 386.5	2	396
PLECOPTERA	Hoover Dam to Davis Dam site	3A	259
Nemouridae	Grand Canyon tributaries	1B	72
	Paria River RM 688.4		
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Kanab Creek RM 546.1		
	National Canyon RM 523.3		

Species	Location	Region	Reference
	ORM 29 - 116.4	1B	71
	Lake Mead	2	232
Bracyptera grinnelli	10th Avenue backwater Sec. 36	4C	304
Capnia spinulosa	10th Avenue backwater Sec. 36	4C	304
Perlidae	Tapeats Creek RM 555.8	1B	72
	Deer Creek RM 553.2	1B	72
	ORM 136.2	1B	71
Perlodidae	Tapeats Creek RM 555.3	1B	72
	Deer Creek RM 553.2	1B	72
	ORM 133.8	1B	71
	Thunder River	1B	71
Isoperla sp.	Tapeats Creek RM 555.3	1B	86
ODONATA	Lake Mead	2	193
	Lake Mead	2	314
	Black Canyon before Davis Dam	3A	259
	Lake Mohave	3A	193
	Lake Mohave	3A	314
	Lake Mohave	3A	104
	below Davis Dam	3B	193
	ORM 430 - 439.9 Mohave Valley	3B	256
	Lake Havasu	3C	199
	Bill Williams Arm, L. Havasu	3C	104
	ORM 524 - 559.9 Parker Division	4A, 4B	256
	Colorado River Indian Reservation	4B	104
	Palo Verde Irrigation District drains	4C	162
	Palo Verde Outfall and Pilot Cut, Cibola NWR	4C	104
	ORM 590 - 596.6 backwaters	4C	256
	Imperial Division	4C	20
	Imperial Reservoir Lakes	4C	417
	ORM 700 - 702 Limitrophe Division backwaters	5C	256
	Hunter's Hole, Limitrophe Division	5C	258
Anisoptera-Dragonflies	below Davis Dam	3B	127
	Parker Dam to Morelos Dam	3,4,5	159
	Imperial Reservoir	4C	152
	Devil Lake, Imperial Reservoir	4C	226
Gomphidae	Paria River RM 688.4	1B	72
	ORM 208.6	1B	71
	ORM 590 - 596.6 Palo Verde Division	4C	256

Species	Location	Region	Reference
Erpetogomphus borealis	10th Avenue backwater Sec. 36	4C	304
Gomphus sp.	ORM 570 - 579.9 Palo Verde Division	4C	256
G. intricatus	10th Avenue backwater Sec. 36	4C	304
G. olivaceus	10th Avenue backwater Sec. 36	4C	156
Progomphus borealis	10th Avenue backwater Sec. 36	4C	304
Aeshnidae	Elves Chasm RM 572.8	1B	86
	Tapeats Creek RM 555.8	1B	86
	Deer Creek RM 553.2	1B	72
	Diamond Creek RM 464.4	1B	86
	ORM .9 to 246.1	1B	71
Libellulidae	ORM 31.9 to 248.4	1B	71
	Grand Canyon tributaries		
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Pipe Creek RM 600.2	1B	72
	Hermit Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Tapeats Creek RM 555.8	1B	86
	Havasu Creek RM 533.0	1B	72
	National Canyon RM 523.3	1B	72
	Diamond Creek RM 464.4	1B	72
	Diamond Creek RM 464.4	1B	86
	Bridge Canyon RM 455.1	1B	72
	Lake Mead	2	232
Zygoptera-Damselflies	Lee Ferry introduced 1965	1A	72
	Lake Mohave	3A	130
	Deer Island Lake, Parker Division RM 172	4B	320
	Imperial Reservoir Lakes	4C	152
Agrionidae	ORM 116.4	1B	71
Coenagrionidae	Grand Canyon tributaries		
	Vasey's Paradise RM 658.1	1B	72
	Vasey's Paradise RM 658.1	1B	86
	Buck Farm RM 647.9	1B	72
	Unkar Creek RM 616.5	1B	72
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.1	1B	72
	Pipe Creek RM 600.2	1B	72

Species	Location	Region	Reference
	Hermit Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72
	Shinumo Creek RM 580.7	1B	72
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Stone Creek RM 557.7	1B	72
	Kanab Creek RM 546.1	1B	72
	Kanab Creek RM 546.1	1B	86
	155 Mile Canyon RM 539.7	1B	72
	Havasu Canyon RM 533.0	1B	72
	National Canyon RM 523.0	1B	72
	Three Springs RM 474.4	1B	72
	Diamond Creek RM 474.4	1B	72
	Diamond Creek RM 474.4	1B	86
	Travertine Falls RM 459.7	1B	72
	Bridge Canyon RM 455.1	1B	72
	ORM 31.8 to 248.4	1B	71
	Lake Mead	2	232
	ORM 590 - 596.6 Palo Verde Division	4C	256
Archilestes _californica_	10th Avenue backwater Sec. 36	4C	304
Enallagma _carunculatum_	10th Avenue backwater Sec. 36	4C	304
_E._ _civile_	Moovalya Pond, Havasu Division	4A	104
Ishnura sp.	Imperial Dam pond	5A	207
Lestidae	ORM .9 - 47.0	1B	71
	Spencer Canyon RM 430 (approx)	2	72
HEMIPTERA	Parker Dam to Morelos Dam	4,5	199
	Deer Island Lake, Parker Division RM 172	4B	323
Corixidae	ORM 34.9 to 246.0	1B	71
	Lake Mead	2	193
Graptocorixa sp.	Mainstem Colorado River	1B	72
	Elves Chasm RM 572.8	1B	86
	155 Mile Canyon RM 539.7	1B	72
	Bridge Canyon RM 455.1	1B	72
_G._ _serrulata_	Elves Chasm RM 572.8	1B	302
	Havasu Creek	1B	302
Tricocorixa sp.	Moovalya Pond, Havasu Division	4A	104
Notonectidae	ORM 34.9 - 208.5	1B	71
	Lake Mead	2	193
	Lake Mead	2	232

Species	Location	Region	Reference
Notonecta sp.	Elves Chasm RM 572.8	1B	86
	155 Mile Canyon RM 539.7	1B	72
	National Canyon RM 523.3	1B	72
	219 Mile Canyon RM 470.8	1B	72
	Bridge Canyon RM 455.1	1B	72
N. lobata	Clear Creek RM 604.9	1B	302
	Elves Chasm RM 572.8	1B	302
	Stone Creek RM 557.7	1B	302
	The Ledges	1B	302
	Havasu Creek RM 533.0	1B	302
Gerridae	ORM 34.9 - 124.0	1B	71
	Lake Mead	2	232
Gerris sp.	Paria River RM 688.4	1B	72
	Buck Farm RM 647.9	1B	72
	Little Colorado R. RM 627.4	1B	72
	Hermit Creek RM 594.4	1B	72
	Elves Chasm RM 572.8	1B	72
	Havasu Creek RM 533.0	1B	72
	Havasu Creek RM 533.0	1B	86
G. remigis	Buck Farm RM 647.9	1B	302
	Clear Creek RM 604.9	1B	302
	Shinumo Creek RM 580.7	1B	302
Belostomatidae	Paria River RM 688.4	1B	72
	Lava Springs RM 510.6	1B	72
	Diamond Creek RM 464.4	1B	72
	Travertine Falls RM 459.7	1B	72
	ORM 246	1B	71
	Lake Mead	2	232
Veliidae	Mainstem Colorado River	1B	72
	Paria River RM 688.4	1B	72
	Buck Farm RM 647.9	1B	72
	Clear Creek RM 604.9	1B	72
	Crystal Creek RM 590.8	1B	72
	Shinumo Creek RM 580.7	1B	72
	Stone Creek RM 557.7	1B	72
	Kanab Creek RM 546.1	1B	72
	Havasu Creek RM 533.0	1B	72
	National Canyon RM 523.3	1B	72
	219 Mile Canyon RM 470.8	1B	72

Species	Location	Region	Reference
	Diamond Creek RM 464.4	1B	72
	Travertine Canyon RM 459.7	1B	72
	ORM 31.9 to 246	1B	71
	Imperial Reservoir	4C	152
Microvelia sp.	Vasey's Paradise RM 658.1	1B	86
	Elves Chasm RM 572.8	1B	86
	Havasu Creek RM 533.0	1B	86
	Diamond Creek RM 464.4	1B	86
M. beameri	Clear Creek RM 604.9	1B	302
	Stone Creek RM 557.7	1B	302
	Havasu Creek RM 533.0	1B	302
M. torquata	Vasey's Paradise Rm 658.1	1B	302
	Buck Farm RM 647.9	1B	302
	Clear Creek RM 604.9	1B	302
	Shinumo Creek RM 580.7	1B	302
	Elves Chasm RM 572.8	1B	302
	Stone Creek RM 557.7	1B	302
	Thunder Creek	1B	302
	The Ledges	1B	302
	Havasu Creek RM 533.0	1B	302
Rhagovelia sp.	Deer Creek RM 553.2	1B	86
	Havasu Creek RM 533.0	1B	86
	Diamond Creek RM 464.4	1B	86
R. distincta	Clear Creek RM 604.9	1B	302
	Little Colorado River RM 627.4	1B	302
	Shinumo Creek RM 580.7	1B	302
	Stone Creek RM 557.7	1B	302
	Havasu Creek RM 533.0	1B	302
Macroveliidae			
Macrovelia hornii	Thunder Creek	1B	302
Gelastocoridae	ORM .8 - 246	1B	71
Gelastocoris oculatus	Stone Creek RM 557.7	1B	302
Hebridae			
Hebrus hubbardi	Buck Farm RM 647.9	1B	302
	Elves Chasm RM 572.8	1B	302
	Stone Creek RM 557.7	1B	302
	Deer Creek RM 553.2	1B	302
	The Ledges	1B	302
H. obscurus	Elves Chasm RM 572.8	1B	302

Species	Location	Region	Reference
Ochteridae			
Ochterus barberi	Stone Creek RM 557.7	1B	302
	Lava Falls RM 510.6	1B	302
O. rotundus	Buck Farm RM 647.9	1B	302
	Elves Chasm RM 572.8	1B	302
	Stone Creek RM 557.7	1B	302
Saldidae			
Saldula pexa	Shinumo Creek RM 580.7	1B	302
	Elves Chasm RM 572.8	1B	302
	Deer Creek RM 553.2	1B	302
	Havasu Creek RM 533.0	1B	302
S. pallipes	Vasey's Paradise RM 658.1	1B	302
	Buck Farm RM 647.9.	1B	302
	Shinumo Creek RM 580.7	1B	302
	Elves Chasm RM 572.8	1B	302
	Havasu Creek RM 533.0	1B	302
TRICOPTERA	introduced 1965 Lee Ferry	1A	72
	Lake Mead	2	232
	below Hoover Dam prior to Davis Dam	3A	193
	Moovalya L. Havasu Division	4A	256
	RM .156 - 163 Parker Division	4B	104
	Palo Verde Irrigation System	4B,4C	396
	Imperial Division	4C	20
	Laguna Division and below	5	396
	Yuma Division above sewage outfall	5B	396
Rhyacophilidae	Bright Angel Creek RM 601.3	1B	72
	Tapeats Creek RM 555.8	1B	72
	Tapeats Creek RM 555.8	1B	86
	219 Mile Canyon RM 470.8	1B	72
	Diamond Creek RM 464.4	1B	86
	Bridge City	1B	72
Polycentropodidae	Grand Canyon tributaries	1B	72
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Travertine Falls RM 459.7		

Species	Location	Region	Reference
Philapotamidae	Grand Canyon tributaries		
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Pipe Creek RM 600.2	1B	72
	Hermit Creek RM 594.4	1B	72
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Tapeats Creek RM 555.8	1B	72
	Deer Creek RM 553.2	1B	72
	Diamond Creek RM 464.4	1B	72
	Diamond Creek RM 464.4	1B	86
	Travertine Falls RM 459.7	1B	72
Psychomyiidae	ORM 109 - 133.8	1B	71
	Grand Canyon tributaries		
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Deer Creek RM 553.2	1B	86
	Diamond Creek RM 464.4	1B	86
Hydropsychidae	ORM 87.8 - 133.8	1B	71
	Grand Canyon tributaries	1B	72
	Paria River RM 688.4		
	Little Colorado River RM 627.4		
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Crystal Creek RM 590.8		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Stone Creek RM 557.7		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	Havasu Creek RM 533.0		
	219 Mile Canyon RM 470.8		
	Diamond Creek RM 464.4		
	Travertine Falls RM 459.7		

Species	Location	Region	Reference
	ORM 524.0 - 559.9 Parker Division	4A,4B	256
	2 miles up, 1 mile down from Agnes Wilson Bridge, Parker	4B	391
Hydropsyche sp.	Grand Canyon tributaries	1B	86
	Bright Angel Creek RM 604.9		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	Havasu Creek RM 533.0		
	Diamond Creek RM 464.4		
	RM 386.5 (Lake Mead)	2	396
	ORM 422 - 439.9 Mohave Valley Division	3B	256
	RM 199.2 (Lake Havasu)	3C	396
	ORM 540 - 549.9 Havasu Division	3C	256
Cheumatopsyche sp.	RM 199.2 (Lake Havasu)	3C	396
Potamyia sp.	RM 21.3, 23.2, 28.0, 34.5, 110.2, 139.6	4C,5	396
	Parker Dam to Morelos Dam	4, 5	159
Hydroptilidae	ORM 65.2	1B	71
	Grand Canyon tributaries		
	Vasey's Paradise RM 658.1	1B	72
	Vasey's Paradise RM 658.1	1B	86
	Little Colorado River RM 627.4	1B	72
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Pipe Creek RM 600.2	1B	72
	Hermit Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Stone Creek RM 557.7	1B	72
	Tapeats Creek RM 555.8	1B	72
	Deer Creek RM 553.2	1B	72
	Kanab Creek RM 546.1	1B	72
	Havasu Creek RM 533.0	1B	72
	Diamond Creek RM 464.4	1B	72
	Diamond Creek RM 464.4	1B	86
	Travertine Falls RM 459.7	1B	72

Species	Location	Region	Reference
Agraylea sp.	RM 199.2	3C	396
	RM 101.5	4C	396
Glossosomatidae	Grand Canyon tributaries	1B	72
	Bright Angel Creek RM 601.3		
	Tapeats Creek RM 555.8		
	Diamond Creek RM 464.4		
	ORM 422 - 429.9 Mohave Valley Division	3B	256
	ORM 540 - 549.9 Parker Division	4B	256
Brachycentridae	Grand Canyon tributaries	1B	72
	Shinumo Creek RM 580.7		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	Thunder River	1B	71
Limnephilidae	ORM 41 - 246	1B	71
	Grand Canyon tributaries		
	Buck Farm RM 647.9	1B	72
	Unkar Creek RM 616.5	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Hermit Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72
	Shinumo Creek RM 580.7	1B	72
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Tapeats Creek RM 555.8	1B	72
	Deer Creek RM 553.2	1B	72
	Kanab Creek RM 546.1	1B	72
	219 Mile Canyon RM 470.8	1B	72
	Diamond Creek RM 464.4	1B	72
	Imperial Reservoir	4B	152
Heliopsychidae	Grand Canyon tributaries	1B	72
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Shinumo Creek RM 580.7		
	Diamond Creek RM 464.4		
Heliopsyche sp.	Diamond Creek RM 464.4	1B	86
Lepidostomatidae	Thunder River	1B	71
Microcaddis sp. (family unk)	Black Canyon area prior to Davis Dam	3A	259

Species	Location	Region	Reference
MEGALOPTERA			
Corydalidae	ORM 52.5 - 248.5	1B	71
Corydalus sp.	Grand Canyon tributaries		
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Bright Angel Creek RM 601.3	1B	86
	Pipe Creek RM 600.2	1B	72
	Hermit Creek RM 594.4	1B	72
	Shinumo Creek RM 580.7	1B	72
	Shinumo Creek RM 580.7	1B	86
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Stone Creek RM 557.7	1B	72
	Kanab Creek RM 546.1	1B	72
	Kanab Creek RM 546.1	1B	86
	Havasu Canyon RM 533.0	1B	72
	Diamond Creek RM 464.4	1B	72
	Travertine Falls RM 459.7	1B	72
	Spencer Canyon RM 43.5 (Approx.)	2	72
C. cornutus	RM 386.5	2	386
LEPIDOPTERA			
Pyralidae	ORM 18.1 - 274.4	1B	71
	Grand Canyon tributaries	1B	72
	Paria River RM 688.4		
	Vasey's Paradise RM 658.1		
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Crystal Creek RM 590.8		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Havasu Creek RM 533.0		
	Travertine Falls RM 459.7		
	Parker Dam to Morelos Dam	4,5	159

Species	Location	Region	Reference
Elophila sp.	RM 396.5	2	396
	RM 196.0	3C	396
	RM 44.0	5A	396
Paragyractis sp.	Grand Canyon tributaries	1B	86
	Vasey's Paradise RM 658.1		
	Bright Angel Creek RM 601.3		
	Shinumo Creek RM 580.7		
	Tapeats Creek RM 555.8		
	Diamond Creek RM 464.4		
COLEOPTERA	Black Canyon below Hoover Dam prior to Davis Dam	3A	259
	Lake Mohave	3A	193
	river below Davis Dam	3B	193
	Lake Havasu	3C	42
	Parker Dam to Parker	4A	396
	Imperial Division - Velian Lake	4C	305
	Imperial Division - Velian Lake	4C	226
	Laguna Dam and below	5	396
Curculionidae	Elves chasm RM 572.8	1B	72
Haliplidae	ORM 94-246.0	1B	71
	Grand Canyon tributaries		
	Hermit Creek RM 594.4		
	Elves Chasm RM 572.8		
	Havasu Creek RM 533.0		
	Diamond Creek RM 464.4		
Dytiscidae	ORM 34.9 - 259.5	1B	71
	Grand Canyon tributaries	1B	72
	Buck Farm RM 647.9		
	Unkar Creek RM 616.5		
	Bright Angel Creek RM 601.3		
	Hermit Creek RM 594.4		
	Crystal Creek RM 588.6		
	Elves Chasm RM 572.8		
	155 Mile Canyon RM 539.7		
	Havasu Creek RM 533.0		
	National Canyon RM 523.3		
	219 Mile Canyon RM 470.8		
	Diamond Creek RM 464.4		
	Bridge City		

Species	Location	Region	Reference
	Lake Mead	2	232
	ORM 422 - 429.9 Mohave Valley Division	3B	256
	ORM 524.5 - 529.9 Parker Division	4A	256
	ORM 540 - 549.9 Parker Division	4B	256
	Imperial Division	4C	152
Cybister ellipticus	10th Avenue backwater, Sec. 36	4C	304
C. explanatus	10th Avenue backwater, Sec. 36	4C	304
Thermonectus marmoratus	Grand Canyon tributaries	1B	86
	Elves Chasm RM 572.8		
	Havasu Creek RM 533.0		
	10th Avenue backwaters, Sec. 36	4C	304
Hydrophilidae	ORM 31.8 - 259.5	1B	71
	Grand Canyon tributaries		
	Vasey's Paradise RM 658.1	1B	72
	Vasey's Paradise RM 658.1	1B	86
	Buck Farm RM 647.9	1B	72
	Helmet Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72
	Elves Chasm RM 572.8	1B	72
	Tapeats Creek RM 555.8	1B	72
	155 Mile Canyon RM 539.7	1B	72
	Havasu Creek RM 533.0	1B	72
	Three Springs Canyon RM 474.4	1B	72
	Diamond Creek RM 464.4	1B	72
	ORM 524.5 - 539.9 Parker Division	4A,B	256
Dactylosternum sp.	RM 178, Moovalya Pond, Havasu Division	4A	104
Dryopidae	Grand Canyon tributaries	1B	72
	Hermit Creek RM 594.4		
	National Canyon RM 523.3		
	Diamond Creek RM 464.4		
	Travertine Falls RM 459.7		
Elmidae	Grand Canyon tributaries		
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Bright Angel Creek RM 601.3	1B	86
	Pipe Creek RM 600.2	1B	72
	Hermit Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72

Species	Location	Region	Reference
	Shinumo Creek RM 580.7	1B	86
	Shinumo Creek RM 580.7	1B	86
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Tapeats Creek RM 555.3	1B	72
	Tapeats Creek RM 555.3	1B	86
	Deer Creek RM 553.2	1B	72
	Deer Creek RM 553.2	1B	86
	Kanab Creek RM 546.1	1B	72
	Havasu Canyon RM 533.0	1B	72
	Havasu Canyon RM 533.0	1B	86
	Bridge Canyon RM 455.1	1B	72
	Thunder River	1B	71
	ORM 422 - 429.9 Mohave Valley Division	3B	256
<u>Neoelmis</u> sp.	RM 386.5	2	396
	RM 199.2	3C	396
Hydroscaphidae			
<u>Hydroscapha natans</u>	Diamond Creek RM 464.4	1B	86
Staphylinidae	Mainstem Colorado River	1B	86
Noteridae	ORM 116.4 - 246.0	1B	71
Pselaphidae	ORM 124 - 208.4	1B	71
Psephenidae	ORM 136.2	1B	71
DIPTERA	Lake Havasu	3C	42
	Moovalya Lake, Havasu Division	4A	256
	Deer Island Lake RM 172	4B	323
	Imperial Division	4C	417
Tipulidae	ORM 16.5 to 246.0	1B	71
	Grand Canyon tributaries	1B	72
	Vasey's Paradise RM 658.1		
	Clear Creek RM 604.9		
	Hermit Creek RM 594.4		
	Crystal Creek RM 590.8		
	Elves Chasm RM 572.8		
	Stone Creek RM 557.7		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	155 Mile Canyon RM 539.7		

Species	Location	Region	Reference
Culicoides sp.	Mainstem Colorado River	1B	86
Leptoconops sp.	ORM 590 - 596.6 Palo Verde Division	4C	256
Dixidae	Grand Canyon tributaries		
	Hermit Creek RM 594.4	1B	72
	Tapeats Creek RM 555.8	1B	86
	Deer Creek RM 553.2	1B	72
Stratiomyidae	ORM 84.1 to 246.0	1B	71
	Grand Canyon tributaries	1B	72
	Vasey's Paradise RM 658.1		
	Nankoweap RM 636.4		
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Crystal Creek RM 590.8		
	Elves Chasm RM 572.8		
	Stone Creek RM 557.7		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	155 Mile Canyon RM 539.1		
	National Canyon RM 523.3		
	Three Springs Canyon RM 474.4		
	219 Mile Canyon RM 470.8		
	Diamond Creek RM 464.4		
	Bridge Canyon RM 455.1		
Euparyphus sp.	Vasey's Paradise RM 658.1	1B	86
	Elves Chasm RM 572.8	1B	86
	Diamond Creek RM 464.4	1B	96
Tabanidae	ORM 0 - 246	1B	71
	Grand Canyon tributaries	1B	72
	Nankoweap RM 636.4		
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Hermit Creek RM 594.4		
	Crystal Creek RM 590.8		

Species	Location	Region	Reference
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Diamond Creek RM 464.4		
	Travertine Falls RM 459.7		
	ORM 422 - 429.9 Mohave Valley Division	3B	256
	ORM 524 - 529.9 Parker Division	4B	256
	ORM 540 - 549.9 Parker Division	4A,B	256
Psychodidae	Grand Canyon tributaries	1B	72
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Diamond Creek RM 464.4		
	Travertine Canyon		
	Travertine Falls RM 459.7		
Marvina sp.	Bright Angel Creek RM 601.3	1B	86
	Elves Chasm RM 572.8	1B	86
	Diamond Creek RM 464.4	1B	86
Dolichopodidae	ORM 0 - 246	1B	71
	Grand Canyon tributaries	1B	72
	Paria River RM 688.4		
	Nankoweap RM 636.4		
	Elves Chasm RM 572.8		
	Diamond Creek RM 464.4		
Ephydridae	ORM 0 - 208.6	1B	71
	Little Colorado River RM 627.4	1B	72
	Stone Creek RM 557.7	1B	72
Empididae	ORM 31.9 - 208.6	1B	71
	Grand Canyon tributaries		
	Vasey's Paradise RM 658.1	1B	86
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Pipe Creek RM 600.2	1B	72
	Hermit Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72
	Shinumo Creek RM 580.7	1B	72
	Elves Chasm RM 572.8	1B	86
	Tapeats Creek RM 555.8	1B	72
	Deer Creek RM 553.2	1B	72

Species	Location	Region	Reference
	Deer Creek RM 553.2	1B	86
	Kanab Creek RM 546.1	1B	72
	Diamond Creek RM 464.4	1B	72
	Diamond Creek RM 464.4	1B	86
Anthomyiidae	Grand Canyon tributaries	1B	72
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	219 Mile Canyon RM 470.8		
	Diamond Creek RM 464.4		
Simulidae	ORM 34.9 to 225.9	1B	71
	Mainstem Colorado River	1B	72
	Grand Canyon tributaries		
	Paria River RM 688.4	1B	72
	Vasey's Paradise RM 658.1	1B	72
	Vasey's Paradise RM 658.1	1B	86
	Little Colorado River RM 627.4	1B	72
	Unkar Creek RM 616.5	1B	72
	Clear Creek RM 604.9	1B	72
	Bright Angel Creek RM 601.3	1B	72
	Bright Angel Creek RM 601.3	1B	86
	Pipe Creek RM 600.2	1B	72
	Hermit Creek RM 594.4	1B	72
	Crystal Creek RM 590.8	1B	72
	Shinumo Creek RM 580.7	1B	72
	Shinumo Creek RM 580.7	1B	86
	Elves Chasm RM 572.8	1B	72
	Elves Chasm RM 572.8	1B	86
	Stone Creek RM 557.7	1B	72
	Tapeats Creek RM 555.8	1B	72
	Tapeats Creek RM 555.8	1B	86
	Deer Creek RM 553.2	1B	72
	Deer Creek RM 553.2	1B	86
	Kanab Creek RM 546.1	1B	72
	Kanab Creek RM 546.1	1B	86

Species	Location	Region	Reference
	Havasu Creek RM 533.0	1B	72
	Three Springs Canyon RM 474.4	1B	72
	219 Mile Canyon RM 470.8	1B	72
	Diamond Creek RM 464.4	1B	72
	Diamond Creek RM 464.4	1B	86
	Travertine Falls RM 459.7	1B	72
	Bridge Canyon RM 455.1		
	Lake Mead	2	314
	Lake Mead	2	232
	Lake Mohave	3A	314
	ORM 422 - 439.9 Mohave Valley Division	3B	256
	below Davis Dam	3B	25
	Davis Dam	3B	127
	California-Nevada boundary south to Topock	3B	181
	Bill Williams Arm, Lake Havasu	3C	104
	ORM 524.5 - 549.9 Parker Division	4A,B	256
	RM 176.5 Parker Division	4B	104
	Colorado River Indian Reservation	4B,4C	104
	Palo Verde Outfall and Pilot Cut, Cibola NWR	4C	104
Prosimulium sp.	RM 21.3, 28.0, 34.5, 44.0, 199.2, 362.0, 386.5	2,3,5	396
Simulium sp.	Lake Mohave	3A	104
	below Davis Dam	3B	127
	RM 199.2	3C	396
	RM 34.5	5B	396
S. vittatum	Davis Dam to 5 miles south of Needles, CA	3B	267
Chironomidae	Glen Canyon to Lee Ferry	1A	365
	Glen Canyon to Lee Ferry	1A	364
	ORM 0 - 246.0	1B	71
	Colorado River mainstem	1B	72
	Grand Canyon tributaries	1B	72
	Paria River RM 688.4		
	Vasey's Paradise RM 658.1		
	Little Colorado River RM 627.4		
	Clear Creek RM 604.9		
	Bright Angel Creek RM 601.3		
	Pipe Creek RM 600.2		

Species	Location	Region	Reference
	Hermit Creek RM 594.4		
	Crystal Creek RM 590.8		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Stone Creek RM 557.7		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	Havasu Creek RM 633.0		
	National Canyon RM 523.3		
	Three Springs Canyon RM 474.4		
	219 Mile Canyon RM 470.8		
	Diamond Creek RM 464.4		
	Travertine Falls RM 459.7		
	Lake Mead	2	193
	Lake Mead	2	232
	Lake Mead	2	314
	Hoover Dam, Willow Beach before Davis Dam	3A	259
	Lake Mohave	3A	193
	Lake Mohave	3A	286
	Lake Mohave	3A	314
	Cottonwood Cove, Lake Mohave	3A	55
	Cottonwood Cove area, Lake Mohave	3A	130
	Lower Colorado River, Davis Dam to Mexico, mainstem and backwaters	3,4,5	256
	Colorado River below Davis Dam	3B	193
	California-Nevada boundary to Topock	3B	181
	Topock Marsh	3B	104
	Bill Williams Arm, Lake Havasu	3C	104
	Parker Dam to Morelos Dam	4,5	159
	RM 177 backwater, Parker Division	4B	104
	Deer Island Lake, RM 172	4B	104
	Colorado River Indian Reservation	4B,4C	104
	2 miles above, 1 mile below Agnes Wilson Bridge	4C	391
	Pilot cut and Palo Verde Outfall, Cibola NWR	4C	104
	Imperial Division Lakes	4C	417
	Imperial Reservoir	4C	152
	Imperial Division backwaters	4C	20
	Hunter's Hole, Limitrophe Division	5C	258

Species	Location	Region	Reference
Pelopiinae			
Clinotanypus sp.	Imperial Reservoir	4C	152
Pelopia sp.	RM 182.5	4A	396
(=*Tanypus* sp.)	RM 44.0	5A	396
T. stellatus	Las Vegas Wash, Lake Mead	2	241
Pentaneura sp.	Shinumo Creek RM 580.7	1B	86
	Elves Chasm RM 572.8	1B	86
	Kanab Creek RM 546.1	1B	86
	Diamond Creek RM 464.4	1B	86
	RM 386.5, 362.1	2	396
	RM 101.5	4C	396
	RM 44, 34.5, 21.3	5	396
Procladius sp.	Elves Chasm RM 572.8	1B	86
	Deer Creek RM 553.2	1B	86
	Diamond Creek RM 464.4	1B	86
P. culiciformis	Las Vegas Wash, Lake Mead	2	241
Hydrobaeninae	Mainstem Colorado River	1B	86
	Grand Canyon tributaries	1B	86
	Paria River RM 688.4		
	Vasey's Pardise RM 658.1		
	Little Colorado River RM 627.4		
	Bright Angel Creek RM 601.3		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	Havasu Creek RM 533.0		
	Diamond Creek RM 464.4		
Corynoneura sp.	Elves Chasm RM 572.8	1B	86
	Tapeats Creek RM 555.8	1B	86
Cricotopus sp.	RM 386.5	2	396
	RM 184, 182.5	4A	396
	RM 101.5	4C	396
	RM 21.3	5C	396

Species	Location	Region	Reference
Spaniotoma sp.	RM 362	2	396
	RM 199, 196	3C	396
	RM 184	4A	396
	RM 139.6	4B	396
	RM 101.5	4C	396
	RM 44	5A	396
	RM 34.5, 27, 23.2	5B	396
	RM 21.3	5C	396
Tendipedinae	mainstem Colorado River	1B	86
(=Chironominae)	Grand Canyon tributaries	1B	86
	Vasey's Pardise RM 658.1		
	Bright Angel Creek RM 601.3		
	Shinumo Creek RM 580.7		
	Elves Chasm RM 572.8		
	Tapeats Creek RM 555.8		
	Deer Creek RM 553.2		
	Kanab Creek RM 546.1		
	Diamond Creek RM 464.4		
Calopsectra sp.	Vasey's Paradise RM 658.1	1B	86
	Shinumo Creek RM 580.7	1B	86
	Tapeats Creek RM 555.8	1B	86
	Diamond Creek RM 464.4	1B	86
Chironomus sp.	Las Vegas Bay, Lake Mead	2	241
(=Tendipes sp)	Topock Gorge backwaters	3B	227
	Backwater 1, 2 miles south I-40 bridge, Topock	3C	227
	2 miles up, 1 mile down from Agnes Wilson Bridge	4C	391
	Imperial Reservoir	4C	152
C. attenuatus	Las Vegas Bay, Lake Mead	2	241
C. riparius	Las Vegas Bay, Lake Mead	2	241
Cryptochironomus sp.	RM 386.5	2	396
	RM 139.6	4B	396
	RM 101.5, 50	4C	396
	RM 23.2	5B	396
C. blarina	Las Vegas Bay, Lake Mead	2	241
Dicrotendipes sp.	Las Vegas Bay, Lake Mead	2	241

Species	Location	Region	Reference
Polypedilum sp.	Las Vegas Wash, Lake Mead	2	241
	RM 199.2	3C	396
	RM 139.6	4B	396
	RM 44.0	5A	396
	RM 21.3	5B	396
Pseudochironomus sp.	RM 386.5	2	396
	RM 139.6	4B	396
	RM 101.5	4C	396
Tendipes sp.	RM 362.1	2	396
(=*Chironomus* sp.)	Below Davis Dam	3B	127
	Davis Dam	3B	127
	RM 182.5	4A	396
	RM 139.6	4B	396
	10th Avenue backwater Sec. 36	4C	304
	RM 101.5	4C	396
	RM 44	5A	396
	RM 28	5B	396
	RM 21.3	5C	396
Tanytarsini			
Tanytarsus confusus	Las Vegas Bay, Lake Mead	2	241
T. mancus	Las Vegas Bay, Lake Mead	2	241

Appendix 8. Zooplankton groups reported from the Colorado River

ROTIFERA

Asplanchna
Filinia
Keratella
Polyarthra

HYDRACARINA

Acarina

CRUSTACEA

COPEPODA

Acanthocyclops vernalis
Cyclops spp
C. bicuspidatus thomasi
Diaptomus spp
Microcyclops spp
Microcyclops spp
M/ edax

CLADOCERA

Alona spp
Bosmina spp
Chydorus spp
C. sphaericus
Daphnia spp
Scapholeberis spp

References 193, 259, 86, 314, 286, 104

Appendix 9. Common aquatic invertebrates and their importance to the fishery.

ORDER and GENUS	IMPORTANCE
Cladocera	
Bosmina	Important as food to small fish
Daphnia	Important as food to small fish
Chydorus	Important as food to small fish
Alona	Some importance as food to small fish
Scapholeberis	Important as food to small fish
Copepoda	
Cyclops	Important as food to small fish
Diaptomus	Important as food to small fish
Macrocyclops	Some importance as food to small fish
Mesocyclops	Important as food to small fish
Rotifera	
Keratella	Some importance as food to small fish
Polyarthra	Some importance as food to small fish
Asplanchna	Some importance as food to small fish
Filinia	Some importance as food to small fish
Hydracrina	
Acrina	Some importance as food to small fish
Oligochaeta	Found in both lakes, used by bottom feeding fishes.
Mollusks	
Limnaea, Physa	Found in both lakes. Occasionally used as food by fish.
Corbicula	Found in both lakes, little importance as food for fish.
Crustaceans	
Gammarus	Found only in Lake Mohave in the Willow Beach area. Commonly used as food by fish.
Crayfish	Found in both lakes, some importance as food for fish.
Insects	
Diptera	
Chironomidae	Found in both lakes, commonly used as food by fish.
Simuliidae	
Odonata	Found in both lakes, occasionally used as food by fish.

from Roden 1978.

Appendix 10. Habitat types and representative invertebrate groups from the Colorado River.

Plant beds	Reference
Mollusca	
Physidae	226
Crustacea	
Palaemonetes paludosus	326
Crayfish	324
Insecta	
Odonata (damselflies)	256
Coleoptera	
Dytiscidae	256
Hydrophilidae	256
Diptera	
Culicidae	256
Tabanidae	256
Algal mats in riffles	
Crustacea	
Copepoda	256
Cladocera	259
Amphipoda	
Gammarus lacustris	259
Shifting sand	
Mollusca	
Corbicula sp.	256
Annelida	
Oligochaeta	256
Insecta	
Diptera	
Chironomidae	256
Soft, stable substrates	
Mollusca	
Snails	159
Corbicula	20, 226
Annelida	
Oligochaeta	20
Insecta	
Odonata (dragonflies)	256
Trichoptera	20

Gravel bars, riffles, rocks

Platyhelminthes	
Turbellaria	256
Mollusca	
Snails	72, 159, 391
Corbicula sp.	256, 391
Annelida	
Oligochaeta	72, 391
Crustacea	
Crayfish	324
Gammarus sp.	127
Insecta	
Ephemeroptera	159, 259
Heptageniidae	256, 391
Baetidae	2560
Plecoptera	259
Odonata (dragonflies)	20, 127, 159, 256
Lepidoptera	159
Trichoptera	20, 259
Hydropsychidae	256, 391
Potamyia sp.	159
Microcaddis sp.	259
Coleoptera	
Hydrobiidae	256
Diptera	259
Tipulidae	256
Simulidae	720, 127, 256
Chironomidae	20, 72, 159, 256, 127, 391

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